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ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS
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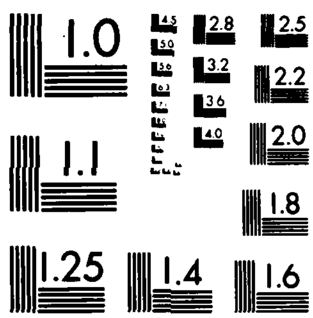

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MISCELLANEOUS PAPER GL-82-18

IN SITU SEISMIC INVESTIGATION OF BLACK BUTTE DAM

by

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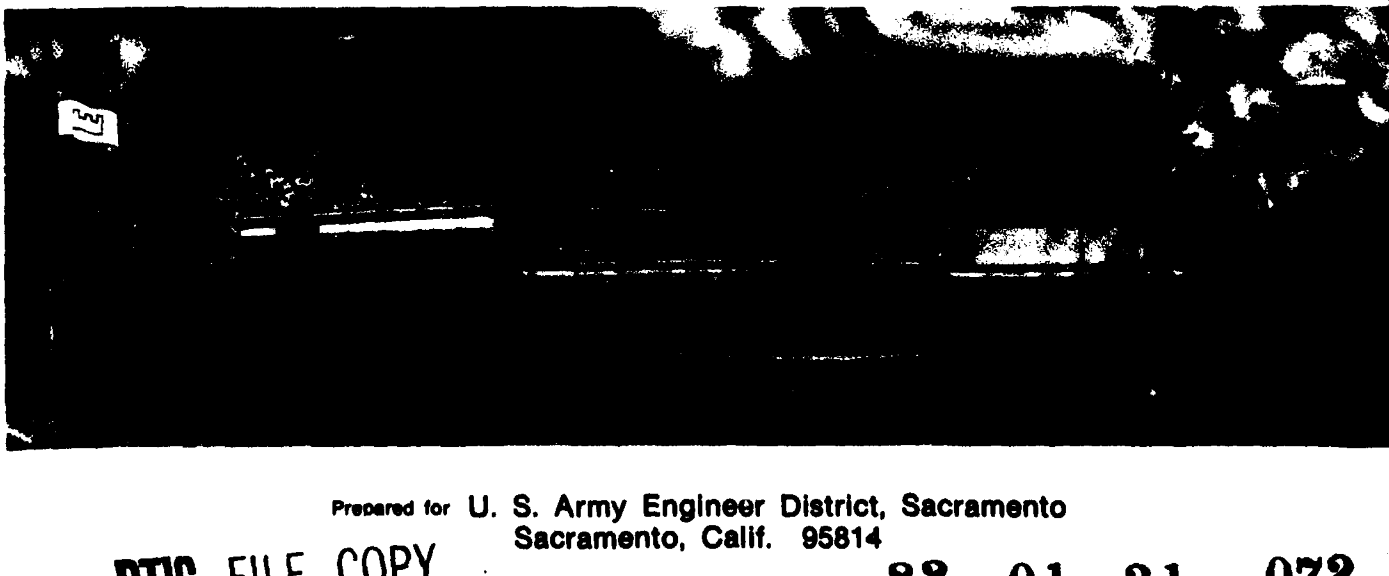
December 1982
Final Report



Prepared for U. S. Army Engineer District, Sacramento
Sacramento, Calif. 95814

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper GL-82-18	2. GOVT ACCESSION NO. AD-A123949	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) IN SITU SEISMIC INVESTIGATION OF BLACK BUTTE DAM		5. TYPE OF REPORT & PERIOD COVERED Final report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) José L. Llopis and Ronald E. Wahl		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Geotechnical Laboratory P. O. Box 631, Vicksburg, Miss. 39180		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, Sacramento Sacramento, Calif. 95814		12. REPORT DATE December 1982
		13. NUMBER OF PAGES 79
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Black Butte Dam
Field tests
Seismic investigations
Seismic waves

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An in situ seismic investigation consisting of surface refraction, surface vibratory, downhole, and crosshole seismic tests was conducted at Black Butte Dam located near Orland, Calif. Compression-, shear-, and Rayleigh-wave (P-, S-, and R-wave) velocities as a function of depth were determined for the Black Butte Dam and underlying foundation materials.

Results of the investigation indicated that P-wave velocities in the dam's core exhibited values of 2150, 5050, and 3050 fps with (Continued)

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20. Abstract (Continued).

increasing depth. The random-fill section indicated velocities of 1825 and 3225 fps. The foundation materials exhibited velocities of 1500, 4400, 6775, and 9850 fps; the first two foundation zones correlated with alluvium while the latter two were representative of the Black Butte Series and Chico Formation, respectively. Materials on the right abutment had velocities of 1225, 3500, and 9825 fps corresponding to slope wash, Tehama Formation, and basalt flows, respectively, while materials on the left abutment were determined to have velocities of 2375 and 8225 fps representative of slope wash and basalt, respectively.

The S-wave velocity profile showed that the dam's core had velocities of 875, 650, and 975 fps with increasing depth. The random-fill section of the dam had velocities of 1100 and 1675 fps. Foundation materials had velocities of 675, 1350, and 1800 fps with the first two velocities representative of alluvium and the third velocity corresponding to the Black Butte Series. R-wave velocities on the right abutment ranged from about 640 to 1125 fps from near surface to a 37-ft depth.

PREFACE

An in situ seismic investigation at Black Butte Dam was authorized by the U. S. Army Engineer District, Sacramento, under IAO Nos. SPKED-F-80-23 and SPKED-F-82-1, dated 3 April 1980 and 14 October 1981, respectively.

The field investigation was performed during the periods 12-15 May 1980 and 18-22 May 1982. Messrs. Ronald E. Wahl, José L. Llopis, Donald E. Yule, Donald H. Douglas, Rodney N. Walters, and Michael K. Sharp, and LT Stephen G. Sanders of the Field Investigations Group, Earthquake Engineering and Geophysics Division (EEGD), Geotechnical Laboratory (GL), and Mr. Monroe B. Savage of the Instrumentation Services Division (ISD), of the U. S. Army Engineer Waterways Experiment Station (WES), were members of the field parties who carried out this project. The analysis phase of this study was performed by Messrs. Wahl and Llopis under the general supervision of Dr. Arley G. Franklin, Chief, EEGD, and Dr. William F. Marcuson III, Chief, GL. This report was written by Messrs. Llopis and Wahl.

COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE, were Commanders and Directors of WES during the performance of this investigation and the preparation of this report. Mr. Fred R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
feet	0.3048	metres
miles (U. S. statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (mass)	0.4535924	kilograms

IN SITU SEISMIC INVESTIGATION OF BLACK BUTTE DAM

PART I: INTRODUCTION

Background, Purpose, and Scope of Study

1. Current computerized seismic wave propagation analysis procedures for earth dams and foundations require that values of compression- and shear-wave (P- and S-wave) propagation velocities as a function of depth be determined. These seismic velocities are used in conjunction with conventional field sampling and laboratory testing to provide soil property information for a dynamic analysis of the dam and its foundation.

2. A geophysical investigation was conducted at Black Butte Dam, which is located on Stony Creek approximately nine miles* west of the town of Orland, Calif., as shown in Figure 1. The investigation was performed to determine P- and S-wave velocities as a function of depth within the dam and its underlying foundation materials. A suite of seismic test methods was used in order to determine an optimal P- and S-wave velocity zonation of the dam and foundation for use in a dynamic analysis.

Site Description

3. The Black Butte Dam is a zoned earth-fill structure with a crest length of 2970 ft, a maximum width of about 700 ft, and a maximum height of 150 ft; construction was completed in 1963. The zones consist of a central impervious core and a random-fill shell. The impervious core trench was founded on rock (basalt) on the abutments and mudstone in the valley section. Depths of excavation for the core trench ranged from approximately 1 to 60 ft. The foundation for the embankment consists of the Chico Formation, the Black Butte Series, and alluvium.

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* A table for converting U. S. customary units of measurement to metric (SI) units is presented on page 3.

4. The Chico Formation consists of sandstone, sandy shales, conglomerates, and a minor amount of limestone. The sediments overlying the Chico Formation are referred to as the Black Butte Series. The basal member is a conglomerate with an average thickness of 25 ft; it is overlain by materials grading upward from a clayey sandstone through a pseudosandstone (i.e., has the appearance of fine-grained sandstone, but is composed of clay to an arenaceous claystone). This material has been grouped under the general heading of mudstone.*

5. The majority of the alluvium upon which the dam is founded consists chiefly of floodplain and stream deposits. The floodplain deposits consist of lenticular deposits of clay, silt, sand, and gravel. These deposits are gray in color, unconsolidated, and have been deposited in such a manner that fines predominately occupy the upper limits with the gravels largely confined to the lower two-thirds. The vertical thickness of this deposit averages 8 ft. The Recent stream deposits are chiefly rounded to subrounded rock fragments (gravel) and are composed of volcanics with minor amounts of diorite, quartzite, schists, and chert. These deposits are porous, loose, and are 17 to 20 ft in vertical thickness.* A plan view of the dam is shown in Figure 2. Transverse and longitudinal cross sections are presented in Figure 3.

Test Program

6. After a preliminary geophysical test program had been planned by personnel of the U. S. Army Engineer District, Sacramento, it was submitted to the U. S. Army Engineer Waterways Experiment Station (WES) for review. Pertinent information relative to the design and construction of the embankment was provided to aid in that review. The finalized test program consisted of seismic refraction, crosshole, downhole, and surface vibratory tests which would provide the geophysical data necessary to complete an analysis of the dam's response to earthquake loadings.

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* Design Memorandum No. 4, Black Butte Project, Stony Creek, Calif., Dam and Appurtenances, Appendix A, 1 January 1959, U. S. Army Engineer District, CE, Sacramento, Calif.

The locations of the tests performed during this investigation are shown in Figure 2. The average pool elevation while conducting surface refraction and vibratory tests was 459 ft (12-15 May 1980). During the performance of crosshole and downhole tests, the average pool elevation was 461 ft (18-22 May 1982).

7. Seismic refraction tests. Surface seismic refraction tests were conducted to determine P-wave velocities, layering (depth to interfaces having contrasting velocities), and anomalous conditions (if any). These tests consisted of four lines, designated R-1 through R-4 which were located and oriented as shown in Figure 2. Forward and reverse traverses were run for each line. Line R-1 was run along the toe of the dam and had a length of 625 ft. Line R-2 was located on the dam crest and was 900 ft long. Line R-3 was run on the right abutment and had a length of 500 ft. Line R-4 was located on the left abutment and had a length of 200 ft.

8. Surface vibratory tests. Ten vibratory lines, designated as V-1 through V-10, were run as shown in the test layout (Figure 2). These tests were conducted to determine Rayleigh-wave (R-wave) velocities, which are similar in magnitude to S-wave velocities, as a function of depth. Lines V-1 through V-4 were located on the dam crest while lines V-5 through V-8 were located on the toe. Lines V-9 and V-10 were run on the right abutment. All the vibratory lines were 200 ft in length.

9. Crosshole tests. Crosshole tests were conducted in three borehole sets (AB, CD, and EF) with each set consisting of two borings. Boreholes in each set were spaced approximately 10 ft apart at the locations shown in Figure 2.

10. The purpose of the crosshole investigation was to determine horizontal P- and S-wave velocities as a function of depth. One advantage of crosshole testing as opposed to surface seismic refraction is its ability to detect lower velocity layers underlying or sandwiched between layers of higher velocity. The crosshole technique is therefore considered to be inherently more definitive and accurate than the surface refraction test but has the shortcoming of requiring boreholes and

not being able to cover as much areal extent; thus the techniques are used in a complementary manner.

11. Borehole set AB was approximately 45 ft deep and was located on the center line of the crest near sta 21+00. These borings were used for obtaining velocities of the impervious core. Borehole set CD was approximately 135 ft deep and located 32 ft below the crest of the dam on the downstream face near sta 21+00; these borings were designed to obtain velocities of the pervious zone, alluvium, and Black Butte Series (i.e., the foundation materials). Borehole set EF was approximately 95 ft deep and located on the downstream toe near sta 21+00; these borings passed through the alluvium and into the Black Butte Series.

12. All borings for the crosshole tests were drilled 8 in. in diameter and cased with 4-in. ID polyvinyl chloride (PVC) pipe by WES personnel. The annular space between the casing and walls of the borings was grouted with a mixture of portland cement, bentonite, and water, which, after setting up, had approximately the consistency of soil. A borehole deviation survey was conducted to determine precise vertical alignment because accurate reduction of data from the crosshole tests requires knowledge of the drift of each borehole so that a straight-line distance between boreholes at each test depth can be established. Since distances and corresponding arrival times were known for each test elevation, an analysis of the crosshole data obtained from each of the three sets was made with the aid of a computer program developed at WES.*

13. Downhole tests. Downhole P- and S-wave tests were conducted to complement surface seismic refraction and crosshole tests thereby increasing overall confidence in data obtained. Downhole P- and S-wave tests were conducted in borings A, C, and E at 5-ft-depth intervals with the source located 5 to 9 ft from the mouth of the borehole. In addition to the determination of P- and S-wave velocities, the downhole test has the ability to detect inversion layers. However, certain limitations must be recognized:

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* Butler, D. K., Skoglund, G. R., and Landers, G. B. 1978. "CROSSHOLE: An Interpretative Computer Code for Crosshole Seismic Test Results, Documentation, and Examples," Miscellaneous Paper S-78-8, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

a. Lower limits of measurable velocity are inherently established by the velocity of the casing or grout which can act as a wave guide for the vertically traveling seismic waves.

b. Accuracy of incremental velocities is directly related to the preciseness of timing control available on the seismograph. In high velocity materials, incremental time differences could be on the order of 1 or 2 msec. Therefore, an error of 0.5 msec in a distance of 10 ft or less would be appreciable. In view of these limitations, the downhole test must be used with discretion.

Equipment and Test Procedures

14. Seismographs. Two different types of seismographs were utilised for recording surface refraction, surface vibratory, crosshole, and downhole test data. Refraction lines R-1 and R-3, and all surface vibratory lines were performed using a portable, battery-powered, 24-channel seismograph, and an oscillograph. Refraction lines R-2 and R-4, crosshole, and downhole tests were conducted with a portable, battery-powered, 12-channel seismograph which had data-enhancement capability.

15. Geophones. For seismic refraction and surface vibratory tests, material response was detected by vertically oriented geophones. For crosshole and downhole tests, the material response was monitored by a triaxial array of geophones (two mounted horizontally at 90 deg to each other, and one vertically oriented) housed in one container.

16. Energy sources. For seismic refraction lines R-1 through R-3 the seismic energy source was 2 to 5 lb of two-component explosive charges with the amount of explosives used being dependent on the length and location of the line. Charges were buried between 3 and 5 ft dependent on the location of the line. For refraction line R-4, the seismic source was generated by applying sledgehammer blows to a steel plate seated on the ground surface.

17. The energy source for the surface vibratory lines was a 4000-lb force (peak) electrohydraulic vibrator with a 10- to 300-Hz frequency range.

18. For crosshole seismic tests, a downhole vibrator was used as a generator of vertically polarized shear (SV) waves. Exploding bridge-wire detonators were used as a P-wave source.

19. The energy source for the determination of P-wave velocities for the downhole test consisted of striking a steel plate, seated on the ground, with a sledgehammer. S-waves for the downhole S-wave test were generated by alternately striking each end of a wooden plank lying on the ground with a sledgehammer.

20. All phases of the geophysical test program with the exception of the surface vibratory and crosshole S-wave tests were conducted in accordance with procedures outlined in Chapter 3 of EM 1110-1-1802, "Geophysical Exploration," dated 31 May 1979. In this manual, a detailed description of each test technique employed is presented along with pertinent background information. The surface vibratory test procedure consisted of positioning the vibrator at a selected location and placing the geophones in a straight line (starting at and extending away from the vibrator) at selected intervals along the surface of the ground. The vibrator was then operated at discrete selected frequencies with the surface R-wave being monitored by the transducers (geophone nearest the vibrator served as zero time). The time lag, referenced to the zero time geophone, is determined and plotted versus the respective distances that the geophones were from the vibrator. The R-wave velocity for the source frequency is determined from the slope of the line obtained in the plot. When the frequency and R-wave velocity are known, a corresponding wavelength can be computed by dividing the velocity by the frequency. Wave velocities thus derived are considered to be average values* for an

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* R-wave velocities that are determined near a high velocity contrast interface, such as a soil-rock boundary, will probably be influenced by both the higher and lower velocity materials and thus provide weighted average velocities dependent on the physical properties of two layers.

effective depth of one-half the wavelength. As mentioned previously, R-wave velocities are numerically close to S-wave velocities. For the range of Poisson's ratios commonly found in soil materials, the maximum difference between R- and S-wave velocities is less than 10 percent.*

21. The crosshole S-wave test differed from that described in EM 1110-1-1802 in that instead of using a surface-mounted vibrator as a seismic source, a downhole vibrator was employed. The procedure consisted of lowering the vibrator in the borehole to a selected test elevation and clamping the vibrator firmly to the sidewalls of the PVC casing by means of an inflatable rubber bladder. When the vibrator was in position, the operator swept the oscillator through a range of frequencies (50- to 500-Hz) and selected one that propagated well (one with a high amplitude) through the transmitting medium. The time required for the transmitted signal to reach the receiver geophone was recorded with a seismograph with enhancement capabilities and the corresponding S-wave velocity determined.

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* Ballard, R. F., Jr. 1964. "Determination of Soil Shear Moduli at Depths by In Situ Vibratory Techniques," Miscellaneous Paper 4-691, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART II: TEST RESULTS

Surface Seismic Refraction Tests

22. Basic data acquired from seismic refraction tests are conventionally displayed in time-distance plots. The data from lines R-1 through R-4 are shown in Figures 4-7, respectively.

23. Seismic refraction line R-1 was located on the toe of the dam between sta 19+00 and 25+25. Four P-wave velocity zones were determined as shown in Figure 4.* The first zone extended to depths of 6 and 16 ft and had an average velocity of 2150 fps. The underlying second zone was encountered to depths of 23 and 42 ft and had a true velocity of 4750 fps. Zone 3 had a true velocity of 6750 fps and ranged from 110 to 115 ft in depth where Zone 4 was encountered with a true velocity of 9850 fps.

24. Seismic refraction line R-2 was run on the crest of the dam approximately between sta 19+00 and 28+00. Three P-wave velocity zones were indicated as shown in Figure 5. The first zone had an average velocity of 1625 fps and extended to depths between 10 and 40 ft. The underlying zone had a true velocity of 2950 fps and ranged between 132 and 136 ft in depth where Zone 3 was encountered with a true velocity of 6875 fps.

25. Seismic refraction line R-3 was located on the right abutment between the outlet channel and downstream toe (sta 12+00 to 17+00) and was oriented in a southeast-northwest direction. Three P-wave velocity zones were detected as shown in Figure 6. The first zone had an average velocity of 1225 fps corresponding to the overburden and ranged from 5 to 11 ft in thickness. Zone 2, corresponding to the Tehama Formation (poorly consolidated, fluvially deposited pebbles, sand, silts, and clays) extended to depths ranging from 18 ft on the northwestern end of the line to 58 ft on the southeastern end and had a true velocity of 3500 fps.

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* All velocities reported are assumed, based on timing resolution and judgment, to have an accuracy of ± 12.5 fps.

Below the above zones, layer 3, which corresponds to the basalt layer, had a true velocity of 9825 fps.

26. The time-distance plot for seismic line R-4 which was located on the dam's left abutment and oriented in an east-west direction is presented in Figure 7. Two velocity zones were determined. The first zone which corresponds to talus (basalt rubble) deposits had an average velocity of 2375 fps with a thickness varying from 34 ft on the western end of the line to 15 ft on the eastern end. The underlying material, basalt, had a true velocity of 8225 fps.

Downhole P-Wave Tests

27. Downhole test results are presented in conventional time versus slant distance (slant distance is nearly equal to depth) plots. Figures 8-10 show the results of downhole P-wave tests conducted at 5-ft-depth intervals in borings A, C, and E, respectively.

28. Figure 8 presents the data collected from the downhole test conducted in boring A, crest of dam, which was 45 ft deep. Two velocity zones were indicated which are tabulated as follows:

Zone	Approximate Depth to Top of Interface. ft	Velocity, fps
1	0	2165
2	25	2750

29. Figure 9 presents the data acquired from the downhole P-wave test in boring C, downstream face, which was 135 ft deep. Four velocity zones were determined as follows:

Zone	Approximate Depth to Top of Interface, ft	Velocity, fps
1	0	1900
2	10	3300
3	105	4000
4	120	6675

30. Figure 10 presents the data collected from the downhole P-wave test conducted in hole E, located on the downstream toe of the dam, which was 95 ft deep. The results indicated three velocity zones tabulated as follows:

Zone	Approximate Depth to Top of Interface, ft	Velocity, fps
1	0	1300
2	12	4375
3	33	7075

Downhole S-Wave Tests

31. Data obtained from downhole S-wave tests are conventionally shown in arrival time versus slant distance plots. Slant distance is almost equal to depth. The results of the downhole S-wave tests conducted in boreholes A, C, and E are presented in Figures 11-13, respectively.

32. Only one velocity zone was detected from the downhole S-wave test conducted in boring A which was located on the crest, as shown in Figure 11. The velocity of this zone was determined to be 925 fps.

33. Figure 12 presents data acquired from the downhole S-wave test conducted in boring C, downstream slope. Two S-wave velocity zones were interpreted as follows:

Zone	Approximate Depth to Top of Interface, ft	Velocity, fps
1	0	1000
2	20	1920

34. Figure 13 presents results from the downhole S-wave test conducted in boring E located on the downstream toe. Two velocity zones were indicated as follows:

Zone	Approximate Depth to Top of Interface, ft	Velocity, fps
1	0	600
2	12	1825

Surface Vibratory Tests

35. The results from the ten surface vibratory lines (V-1 through V-10) are shown as R-wave velocity versus depth plots which are presented in Figures 14-18. A best-fit curve was drawn through the points in each plot to obtain the velocity profile.

36. Figure 14 presents the R-wave velocity versus depth data for lines V-1 and V-2 which were run on the paved service road on the crest of the dam approximately between sta 18+00 and 22+00. The velocities ranged between 700 and 950 fps and were nearly constant at about 900 fps between depths of 5 and 10 ft below which the velocity decreased quite rapidly to about 700 to 750 fps. Below 15 ft, the velocity gradually increased to 950 fps to a depth of 60 ft. The higher velocities encountered near the surface are probably due to a higher shear modulus associated with the pavement and subgrade materials.

37. Figure 15 presents the R-wave velocity versus depth plot for vibratory lines V-3 and V-4 which were run on the crest of the dam between sta 24+00 and 28+00. The best-fit curve for these lines showed a decrease in velocity from 830 fps at 6 ft to 700 fps at 9 ft. From 9 to 27 ft, the velocity remained fairly constant at 700 fps. Below 27 ft, there is a gradual increase to about 900 fps at a depth of 55 ft.

38. Figure 16 presents the R-wave velocity versus depth for lines V-5 and V-6 which were located on the toe of the dam between sta 24+00 and 28+00. The best-fit curve showed a nearly constant velocity of about 700 fps to a depth of 10 ft at which point the velocity increased almost linearly with depth to 1000 fps at 27 ft.

39. Figure 17 presents the results from vibratory lines V-7 and V-8 run on the toe of the dam approximately between sta 19+00 and 23+00. The best-fit curve indicated a decrease in velocity from 800 to 750 fps in the 6 to 8-ft-depth range. Below 8 ft, the velocity increased almost linearly to 1000 fps at a depth of 27 ft.

40. Figure 18 presents results from vibratory lines V-9 and V-10 which were run on the right abutment of the dam between sta 13+00 and 17+00. Two best-fit lines were drawn for the data. Data from line

V-9 exhibited a linear increase in velocity with depth ranging from 640 fps at approximately 6 ft to 950 fps at about 33 ft. Velocities from lines V-9 and V-10 coincided between depths of 6 and 10 ft and appeared to correlate with the overburden materials. At a depth of approximately 10 ft, the velocity from line V-10 indicated a sharp increase to about 750 fps and then began to increase almost linearly with depth to 1125 fps at 37 ft. The depth to the higher velocity basalt is less below line V-10 than line V-9; therefore, a higher R-wave velocity is exhibited by line V-10 because of the R-wave averaging characterisitcs near a high-velocity contrast interface.

Crosshole Tests

41. The calculated true P- and S-wave velocities as determined by the crosshole computer program at each test elevation for the three crosshole sets are presented in Figure 19. As noted, test elevations were at 5-ft intervals except for crosshole set EF (toe) where no data were obtained from the S-wave test in the upper 10 ft. Also shown in Figure 19 are P- and S-wave velocity zones and depths to interfaces as established by the computer program and judgment.

42. The P-wave velocities for crosshole set AB representative of the core material indicated three velocity zones as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	2950
2	27	5050
3	33	3450

43. The S-wave velocity zones for crosshole set AB indicated three zones as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	825
2	13	525
3	23	1050

44. The P-wave velocity zones for crosshole set CD representative of the pervious zone and foundation materials are as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	1750
2	10	3150
3	113	4600
4	121	6550

45. The S-wave velocity zones for crosshole set CD are as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	1200
2	36	1550
3	114	1400
4	121	1700

46. The P-wave velocity zones for crosshole set EF representative of the dam's foundation materials are as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	1275
2	10	4375
3	24	6875

47. The S-wave velocity zones for crosshole set EF are as follows:

Zone	Depth to Top of Interface, ft	Velocity, fps
1	0	--
2	15	1175
3	27	1850

Data Consolidation

48. In order to make a meaningful interpretation of the data acquired at various locations along the dam using the four different geophysical techniques, it is convenient to present the data in

composite form so that a zonal interpretation can be developed using all the available data. Such composites were prepared for P- and S-wave tests conducted in the vicinity of the cross section near 21+00 and are presented in Figures 20 and 21, respectively.

49. As shown in Figure 20, three zones of the dam were tested: core, random (pervious), and foundation beneath and at the toe of the dam. Results determined from seismic refraction, downhole, and crosshole tests are presented for the core and foundation materials at the toe, while downhole and crosshole results are depicted for the random zone. Comparison of the results from each test for a specific zone are generally in good agreement on velocities and depths to interfaces.

50. As depicted in the S-wave composite (Figure 21) tests were conducted in the same three zones shown in the P-wave composite. Results from crosshole, downhole, and surface vibratory tests are presented for the dam core and foundation materials at the toe. Results from the downhole and crosshole tests are presented for the random zone and foundation material beneath the dam. Velocities and depths to interfaces differ somewhat due to varying limitations between test techniques.

PART III: INTERPRETATION

P-Wave Velocities

51. The P-wave velocity composite (Figure 20) was analyzed and a zonal interpretation made for sta 21+00 using weighted averaging and judgment based on data quality and the limitations and advantages of each test performed. Since the borings on the crest did not penetrate the foundation materials, thus preventing the acquisition of data from downhole and crosshole tests, two approaches were used to present values for use in this region for the seismic wave propagation analysis. The first approach does not involve the extrapolation or interpolation of velocities beyond areas in which measurements were made, and is presented in Figure 22. The zoning through the core and underlying foundation revealed four velocity zones. The first zone had a velocity of 2150 fps and extended to a depth of about 25 ft. The second zone had a velocity of 5050 fps with a thickness of 8 ft. It will be noted that both the seismic refraction and downhole P-wave tests failed to discern this layer; however, it was detected by the crosshole P-wave test. Even though only one out of three tests distinguished this faster layer, it was felt that it should be reported since the boring logs indicated the highest blow counts occurred in this zone. Underlying the above zones was a 3050-fps layer which extended to approximately 150 ft (the dam-foundation contact). The fourth zone corresponding to the Black Butte Series had a velocity of 6875 fps to undetermined depths. Four velocity zones were interpreted for the random material. The first zone had a velocity of 1825 fps and extended to a depth of 10 ft. The underlying second zone extended to a depth of about 110 ft with a velocity of 3225 fps. Underlying the above layers was a third zone having a velocity of 4300 fps which corresponded with the alluvium. At a depth of about 122 ft, the Black Butte Series was encountered with a velocity of 6625 fps to 135 ft. The tests conducted at the downstream toe of the dam revealed four P-wave velocity zones for the foundation material. The near-surface layer exhibited a velocity of 1500 fps and had a

thickness of 10 ft. The second zone had a velocity of 4500 fps and extended to a depth of 27 ft. The first two zones correlated with the alluvium. The Black Butte Series was encountered at a depth of 27 ft and had a velocity of 6900 fps. The seismic refraction line exhibited a fourth zone having a 9850 fps velocity at a depth of about 111 ft. It is possible that this zone corresponds to the Chico Formation.

52. The second approach for interpreting P-wave data was to assign zonal velocities according to constructed zones of the dam and foundation layering this involves some interpolation and extrapolation based on the principle that with other things being equal seismic wave velocities increase with effective stress. The results of this method are presented in Figure 23 for the cross section through sta 21+00. Three velocity zones were interpreted for the core (Figure 23). The upper 25 ft of core material had a velocity of 2150 fps while the underlying second zone had a velocity of 5050 fps. The lateral extent of the second layer cannot be predicted. The core, from a depth of 33 ft to the dam-foundation contact, had a velocity of 3050 fps. The random zone exhibited two velocity zones. The upper 10 ft of random zone material had a velocity of 1825 fps. The rest of the random zone was assigned a velocity of 3225 fps. Results of testing in the foundation materials yielded four velocity zones. The first zone which was encountered only at the downstream toe had a thickness of 10 ft and a velocity of 1500 fps. The second zone exhibited a velocity of 4400 fps and correlated with the alluvial sand and gravel layer. The third zone, indicative of the Black Butte Series, had a velocity of 6775 fps. The thickness (about 84 ft) of the Black Butte Series was measured only at the toe of the dam. Underlying the Black Butte Series, the Chico Formation was encountered with a corresponding velocity of 9850 fps at a depth of about 111 ft.

S-Wave Velocities

53. S-wave zonal interpretations were made in the same manner as employed for P-wave interpretations previously discussed. Figure 24

presents the S-wave zonal velocity interpretation through the cross section at sta 21+00. Three zones were determined for the core. The first zone extended to a depth of 12 ft and had a velocity of 875 fps. The underlying zone with a velocity of 650 fps extended to a depth of 22 ft where the third zone was encountered with a velocity of 975 fps to a depth of 45 ft, the limit of testing. The velocity profile through the random zone and into the foundation revealed four zones. The first zone, 28 ft thick, exhibited a velocity of 1100 fps. The second zone which extended to the dam-foundation contact had a velocity of 1675 fps. The alluvium directly beneath the dam had a velocity of 1400 fps and a thickness of about 7 ft. A velocity of 1750 fps was detected at 121 ft deep and is probably indicative of the Black Butte Series. Interpretation of data obtained at the downstream toe of the dam revealed three zones. The first zone, corresponding to alluvium, had a velocity of 675 fps and a 15-ft thickness. The underlying zone also corresponded to alluvium and had a velocity of 1300 fps extending to 27 ft in depth where the Black Butte Series was encountered. The Black Butte Series in the toe area was determined to have a 1825 fps velocity to a depth of 95 ft, the extent of testing.

54. The second interpretation approach (based on constructed zones of the dam) is presented in Figure 25. The core is divided into three zones. The first zone was 12 ft thick with a velocity of 875 fps. The second zone which ranged from 12 to 22 ft in depth had a velocity of 650 fps. The third zone extended from a depth of 22 ft to the dam-foundation contact and exhibited a velocity of 975 fps. The random zone of the dam was divided into two velocity layers. The upper 28 ft of random material had a velocity of 1100 fps. The rest of the random material was interpreted to have a velocity of 1675 fps. The foundation materials were divided into three velocity zones. The first zone corresponding to the near-surface materials at the toe, had a thickness of about 15 ft and a velocity of 675 fps. Underlying the above zone and extending laterally to the transition zone was a layer with a velocity of 1350 fps and an average thickness of about 10 ft. The above two zones corresponded to the alluvial materials. Beneath the alluvium, a velocity

of 1800 fps was encountered which correlated with the Black Butte Series.

PART IV: CONCLUSIONS

55. The following conclusions were drawn as a result of the in situ investigation conducted at Black Butte Dam.

56. The interpretation of P-wave data indicated three velocity zones in the core and two velocity zones for the random fill. The core had velocities of 2150, 5050, and 3050 fps while the random zone had velocities of 1825 and 3225 fps. The foundation materials investigated consisted of alluvium and materials belonging to the Black Butte Series and Chico Formation. The alluvium on which the dam rests had a velocity of 4400 fps. At the toe of the dam, the 4400-fps alluvium is overlain by alluvium having a velocity of 1500 fps. Underlying the alluvium is the Black Butte Series which had a velocity of 6775 fps. The Chico Formation had a velocity of 9850 fps and was encountered only by the refraction seismic test conducted at the toe.

57. Results from seismic refraction tests indicated three velocity zones for the right abutment of the dam. The first zone, slope wash, had a velocity of 1225 fps. The second zone, corresponding to the Tehama Formation, had a velocity of 3500 fps while the third zone, basalt flows, had a velocity of 9825 fps. The left abutment had velocities of 2375 and 8225 fps which correlated with slope wash and basalt, respectively.

58. The S-wave velocity profile for Black Butte Dam showed that the core had three velocity zones of 875, 650, and 975 fps. The random zone was interpreted to have velocities of 1100 and 1675 fps. For the foundation, alluvial material in the vicinity of the downstream toe, had a 675 fps velocity and a thickness of 15 ft. For the remainder of the alluvium at the toe and extending beneath the dam to the transition zone, a velocity of 1350 fps was noted. The Black Butte Series, which underlies the alluvium, was determined to have a velocity of 1800 fps.

59. Results from surface vibratory tests conducted on the right abutment indicated that R-wave velocities ranged from 640 fps near the surface to 1125 fps at a depth of 37 ft.

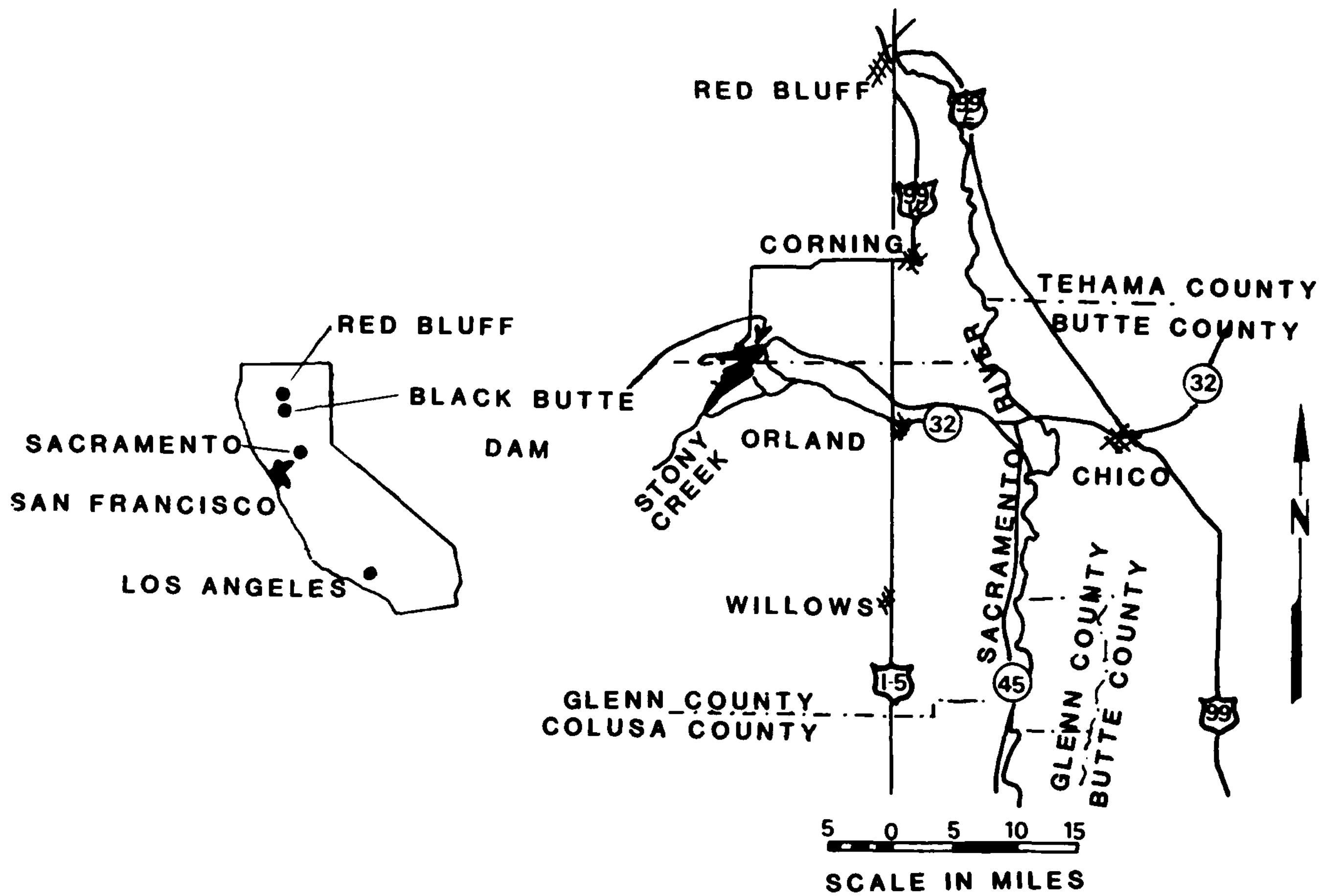


Figure 1. Locality map

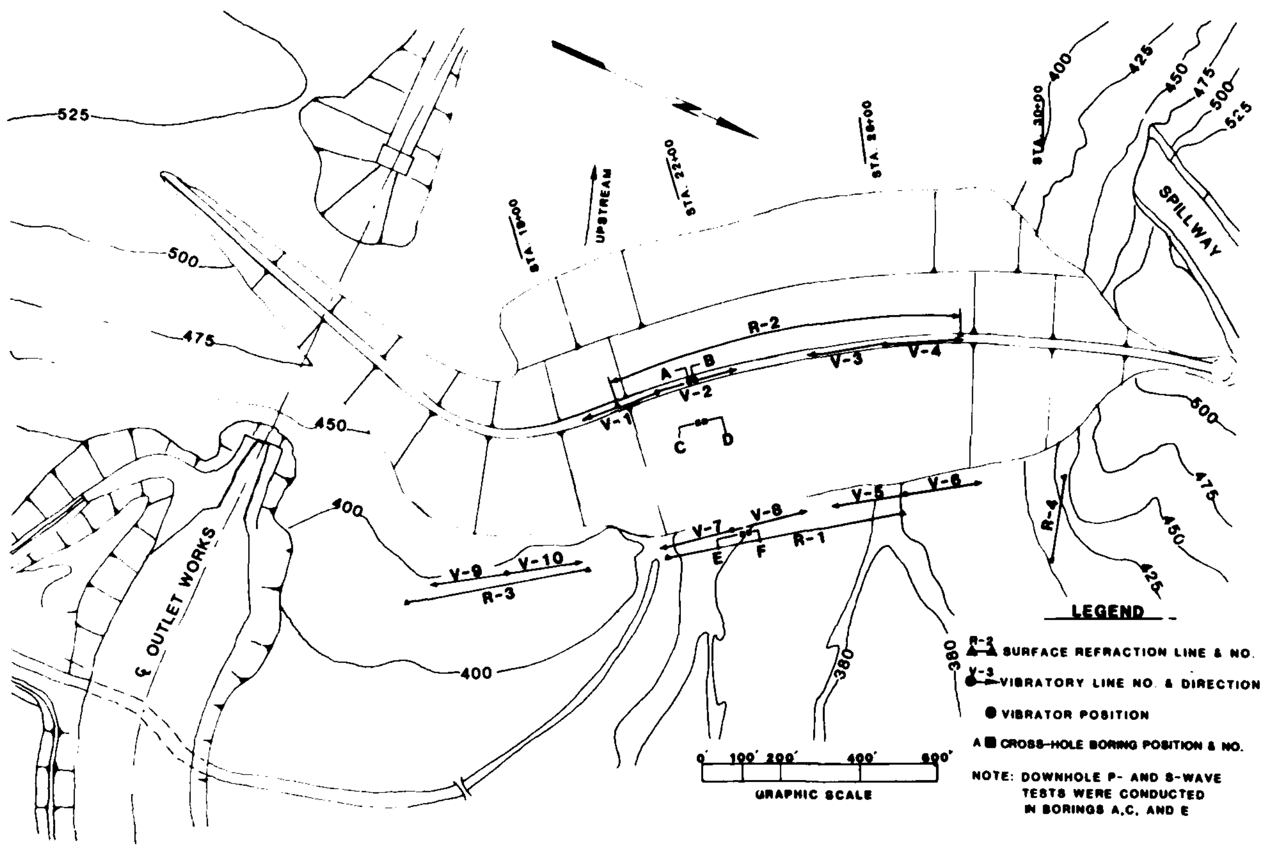
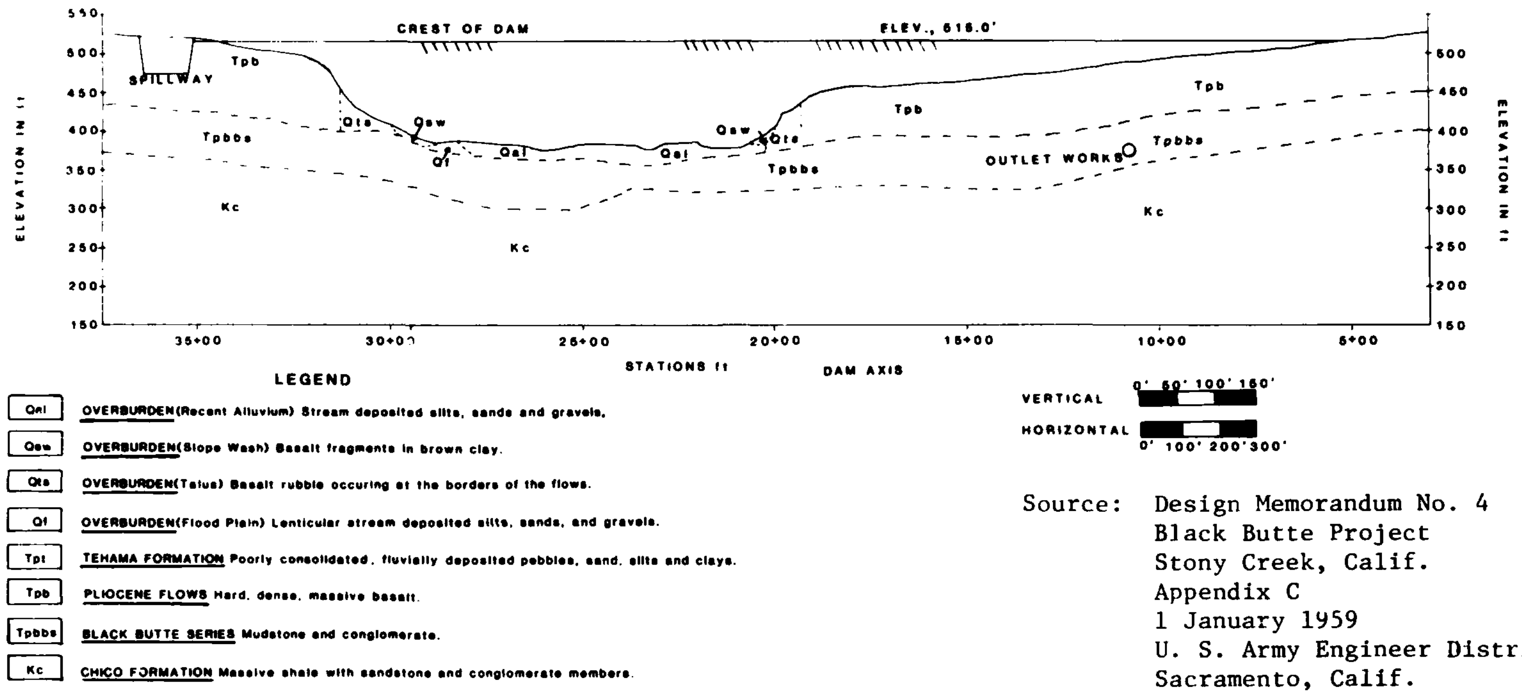


Figure 2. Plan view and test layout of Black Butte Dam



Source: Design Memorandum No. 4
Black Butte Project
Stony Creek, Calif.
Appendix C
1 January 1959
U. S. Army Engineer District, CE
Sacramento, Calif.

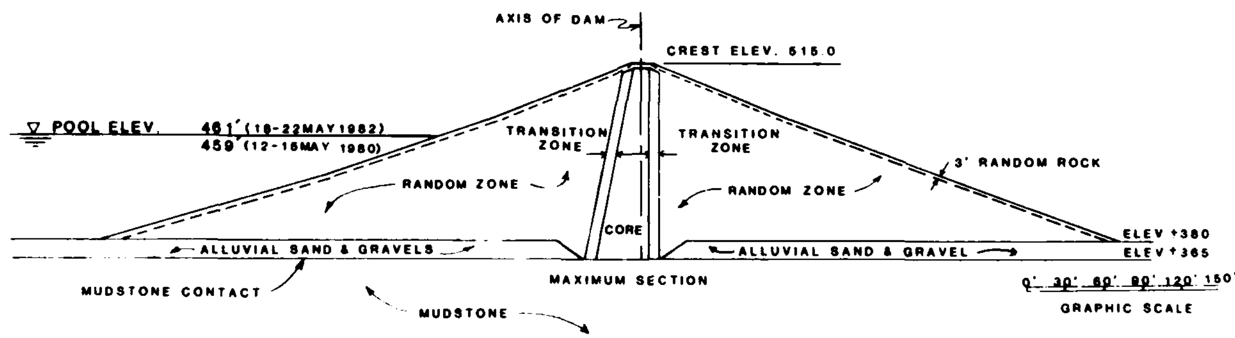


Figure 3. Cross section of Black Butte Dam

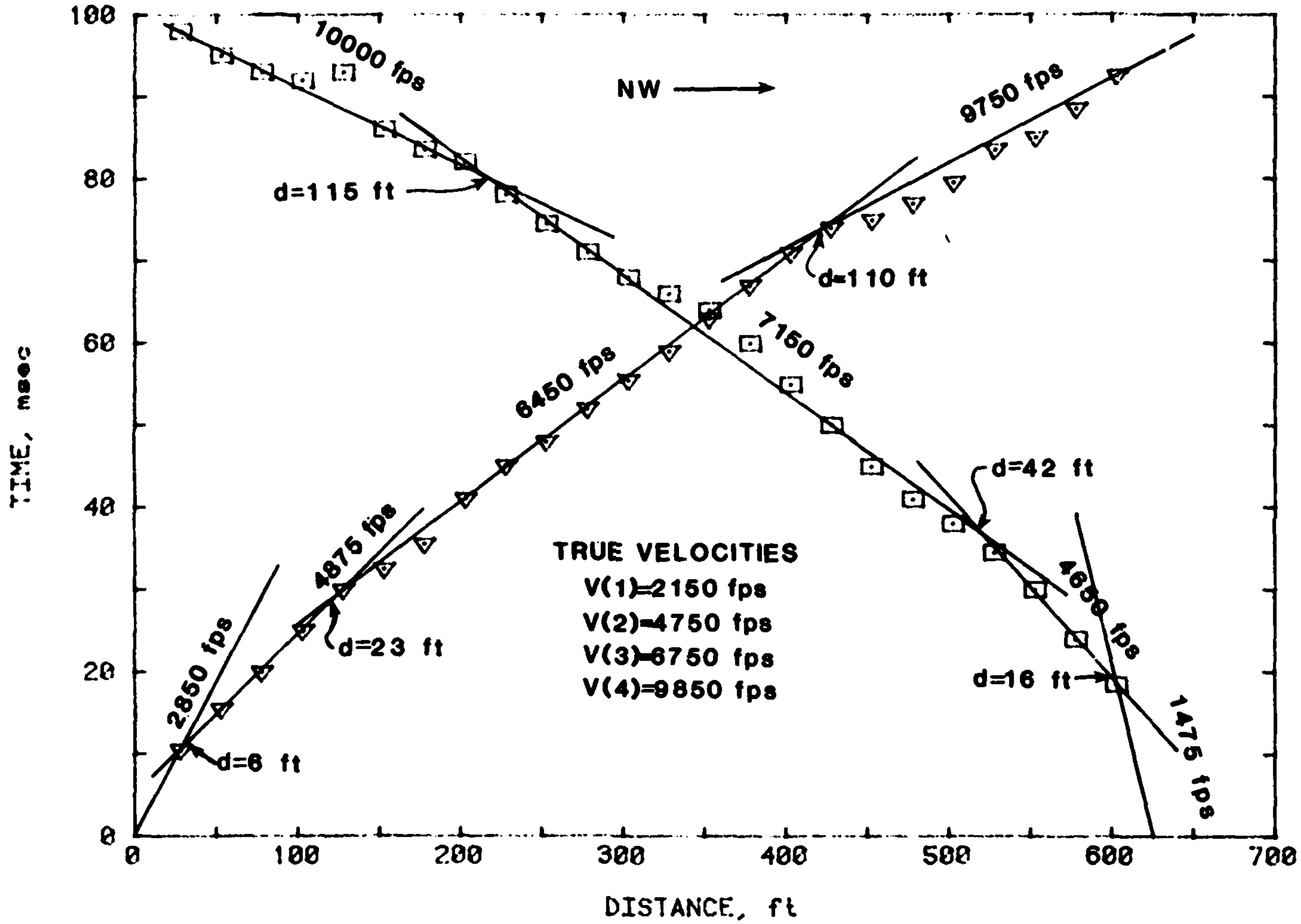


Figure 4. Surface refraction line R-1, toe of dam

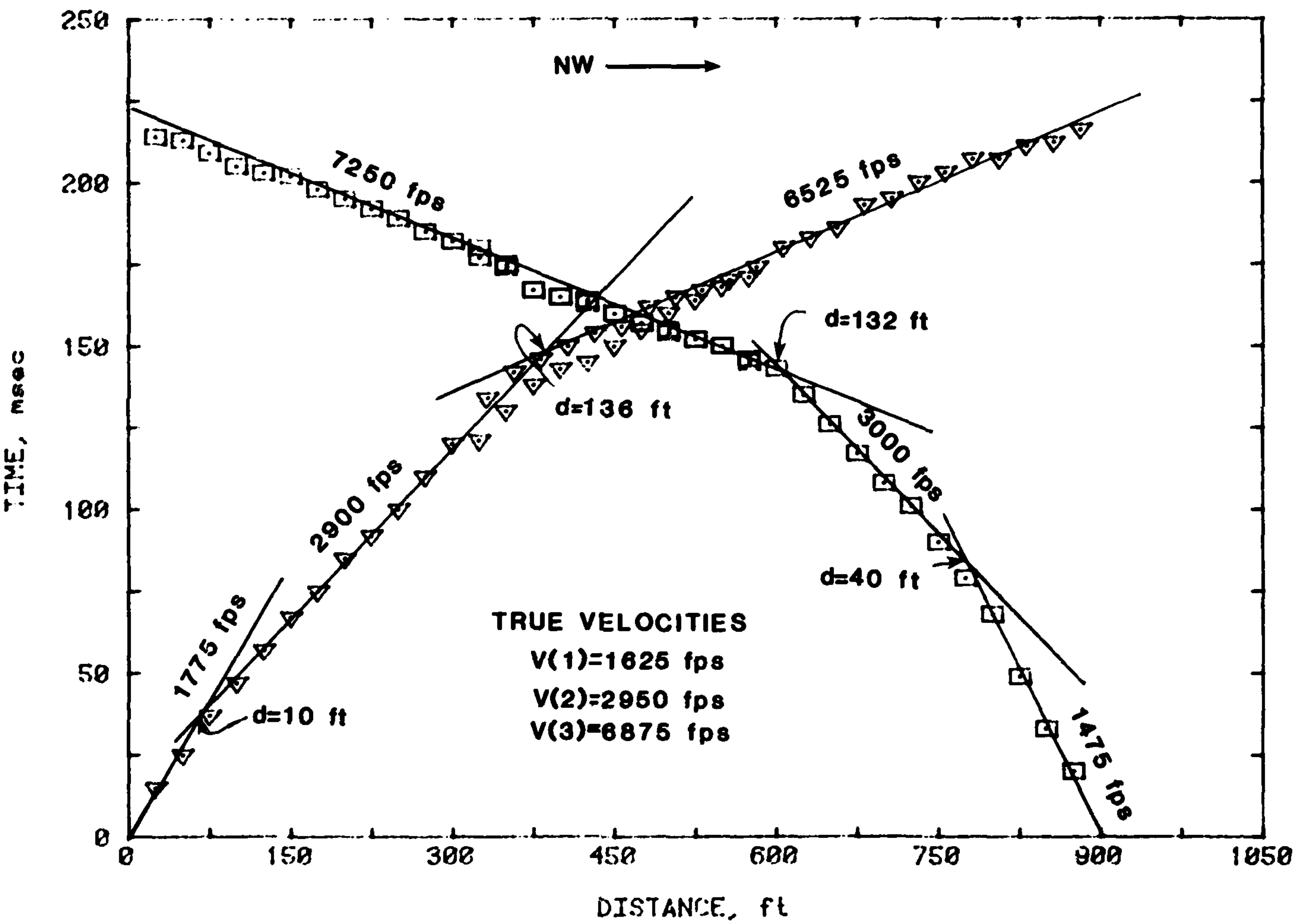


Figure 5. Surface refraction line R-2, crest of dam

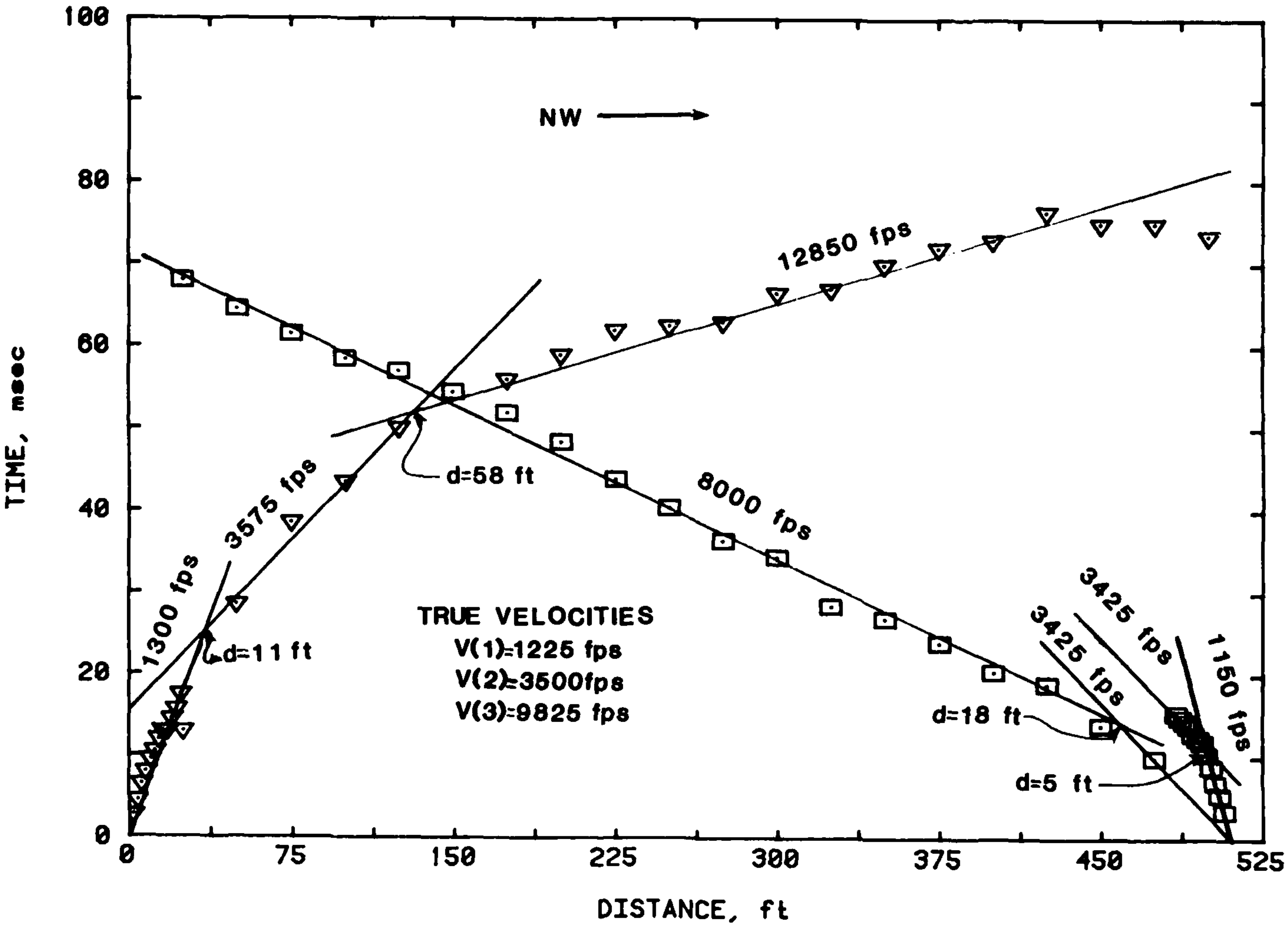


Figure 6. Surface refraction line R-3, right abutment of dam

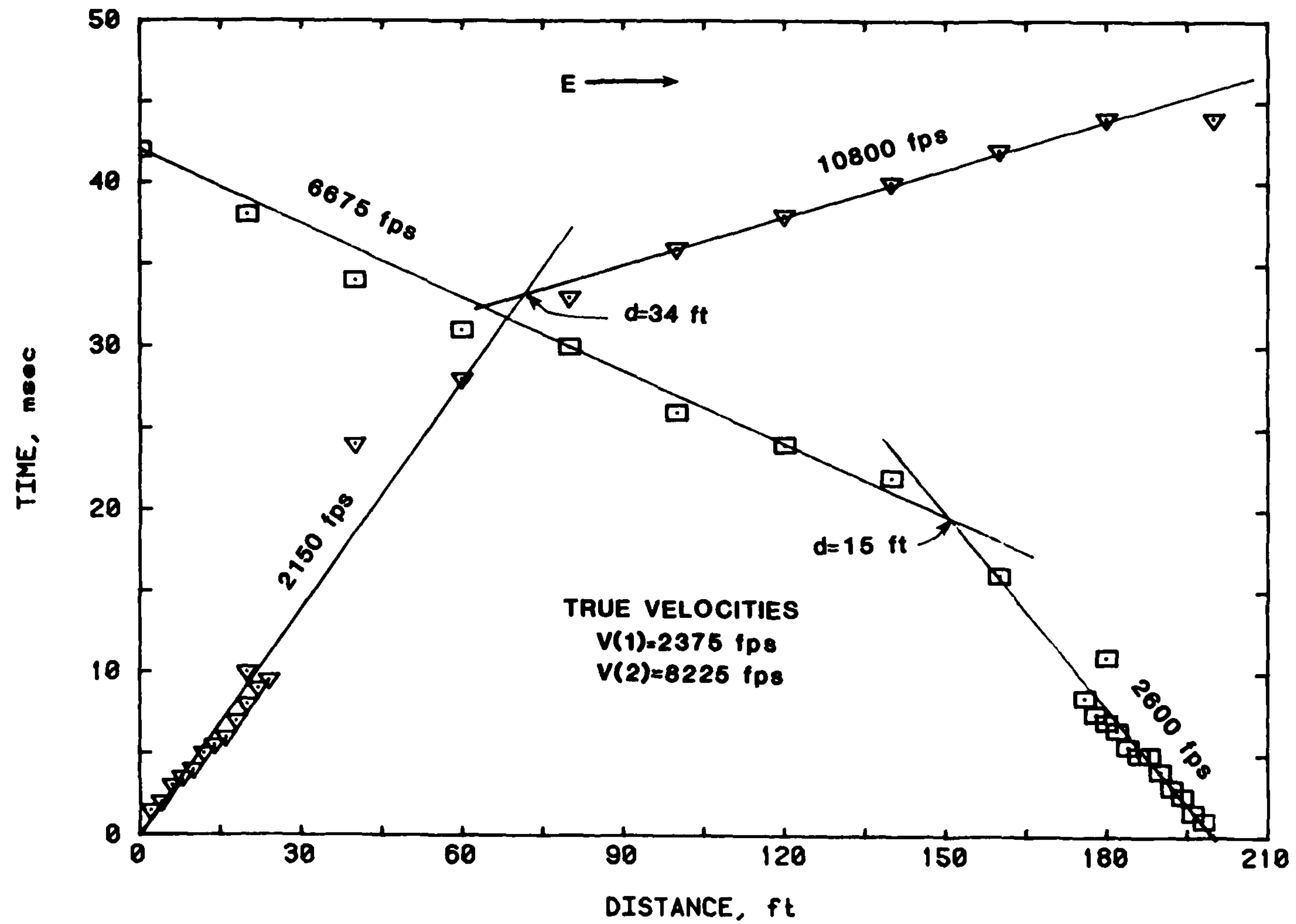


Figure 7. Surface refraction line R-4, left abutment of dam

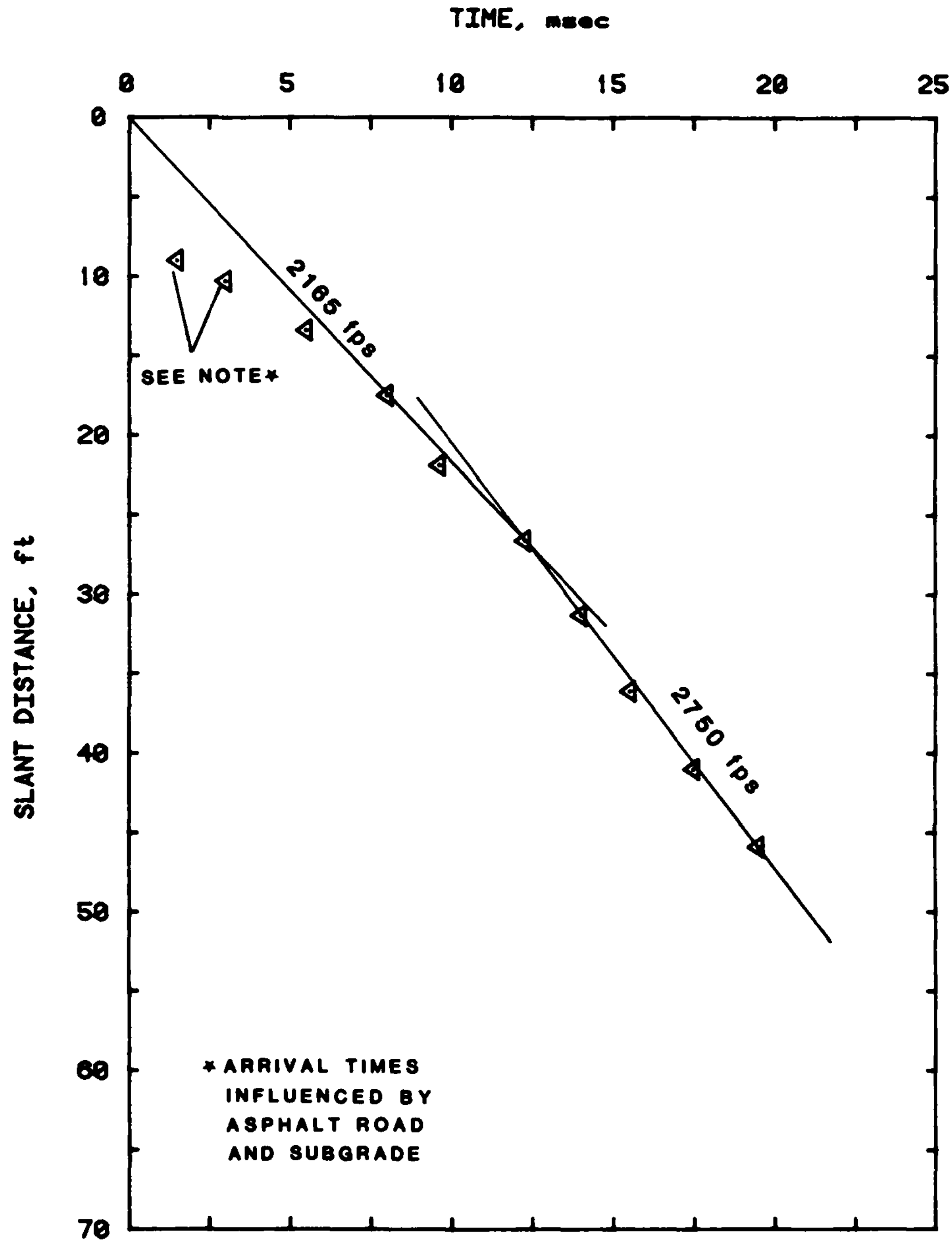


Figure 8. Downhole P-wave test conducted in borehole A, crest of dam

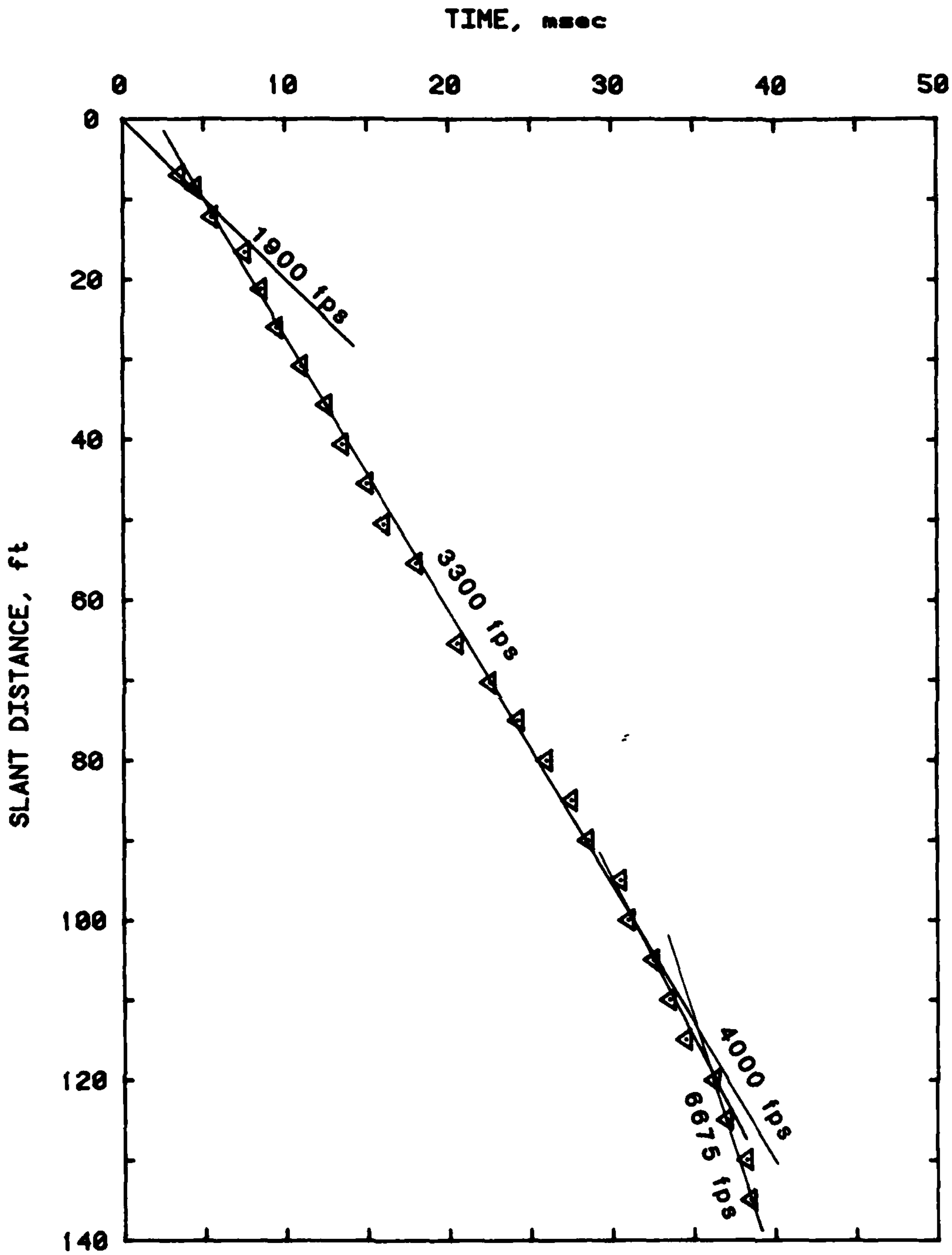


Figure 9. Downhole P-wave test conducted in borehole C, downstream slope of dam

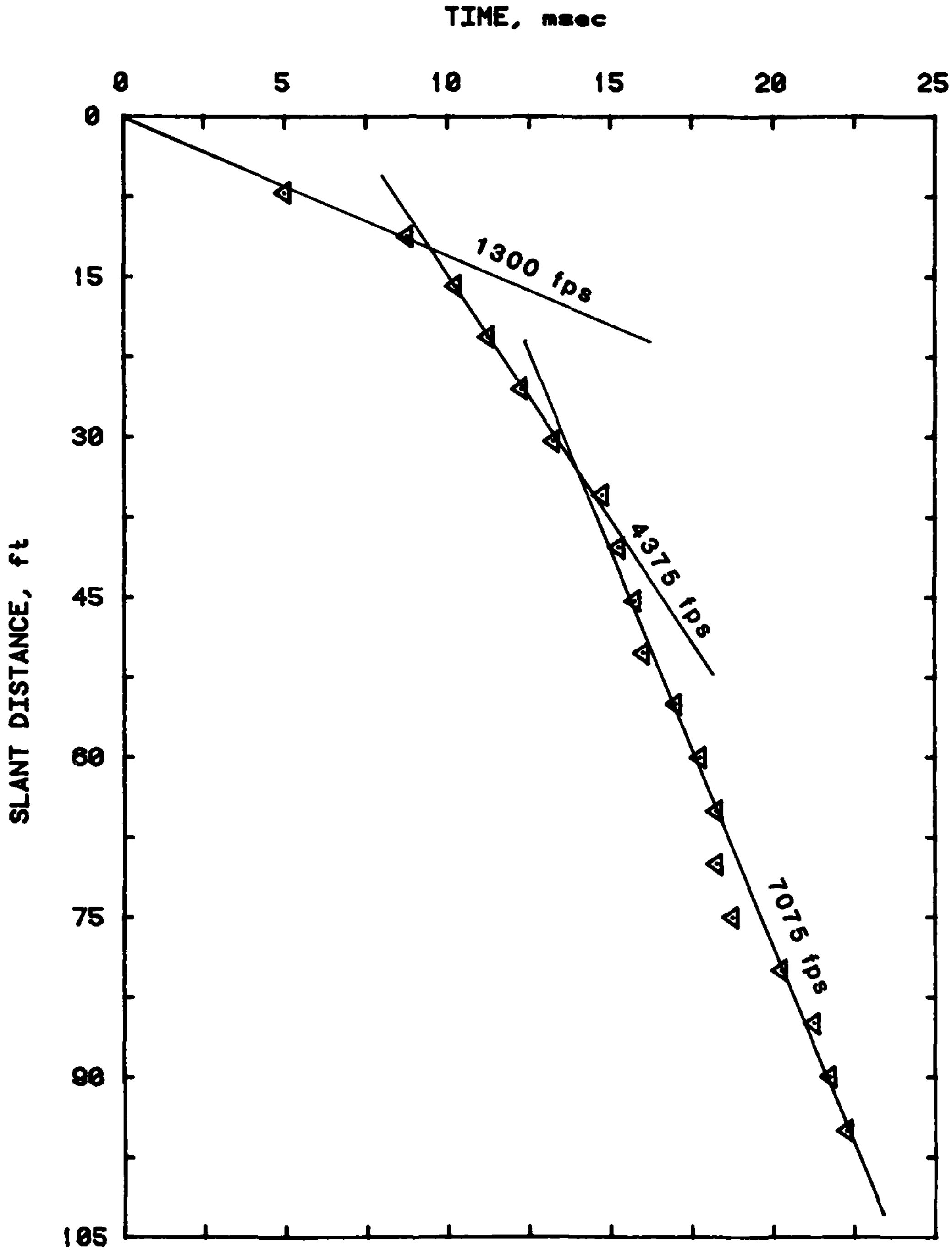


Figure 10. Downhole P-wave test conducted in borehole E, downstream toe of dam

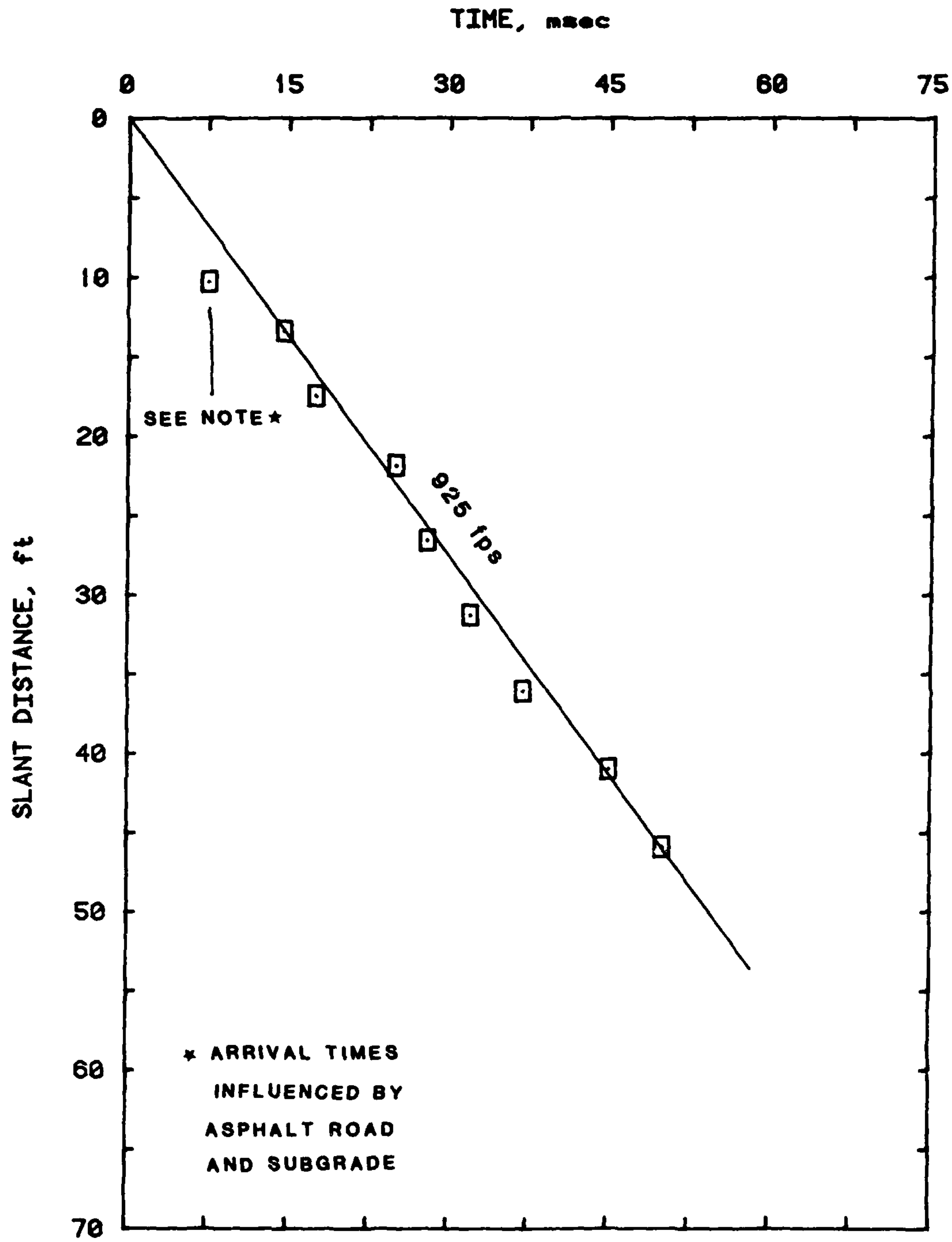


Figure 11. Downhole S-wave test conducted in borehole A, crest of dam

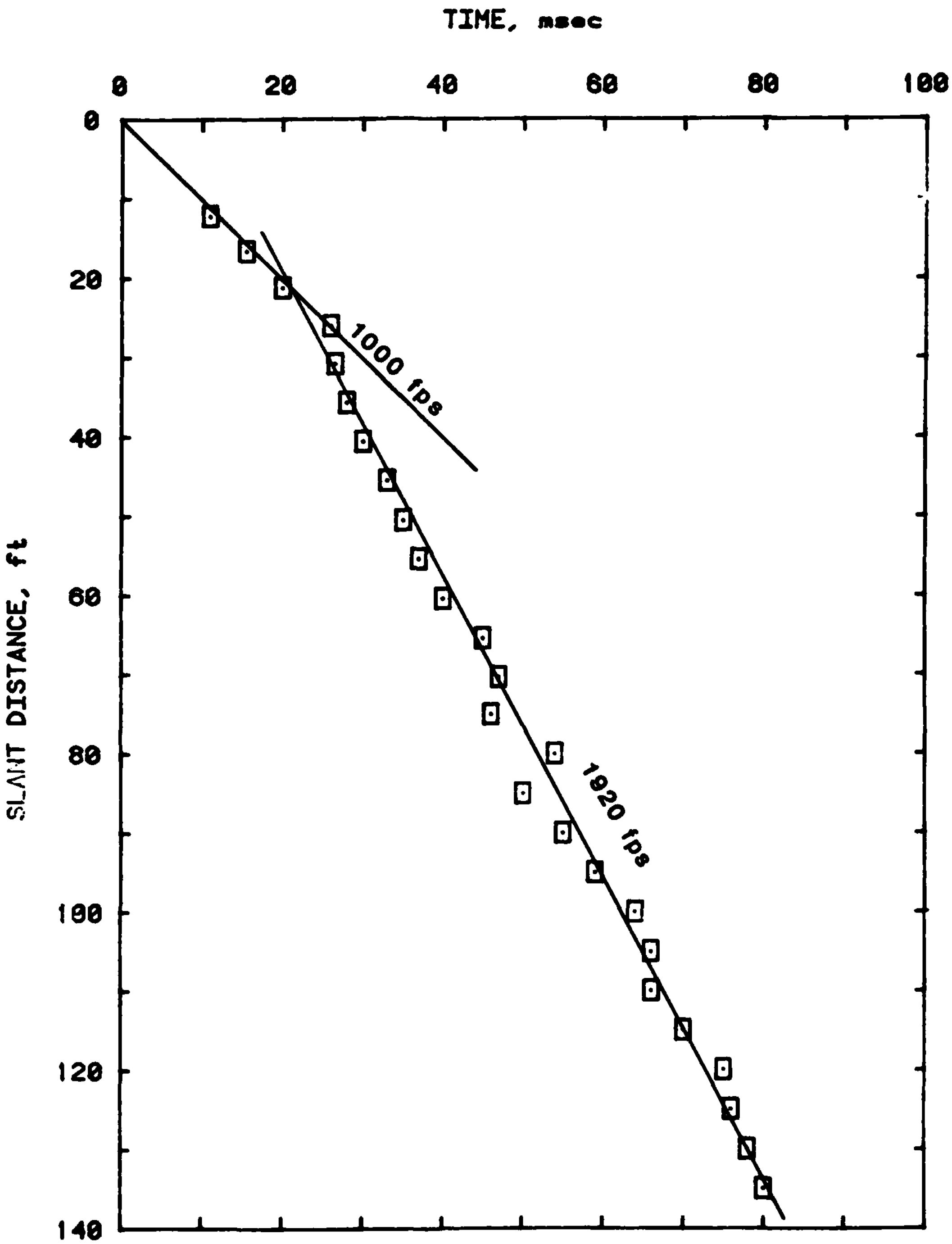


Figure 12. Downhole S-wave test conducted in borehole C, downstream face of dam

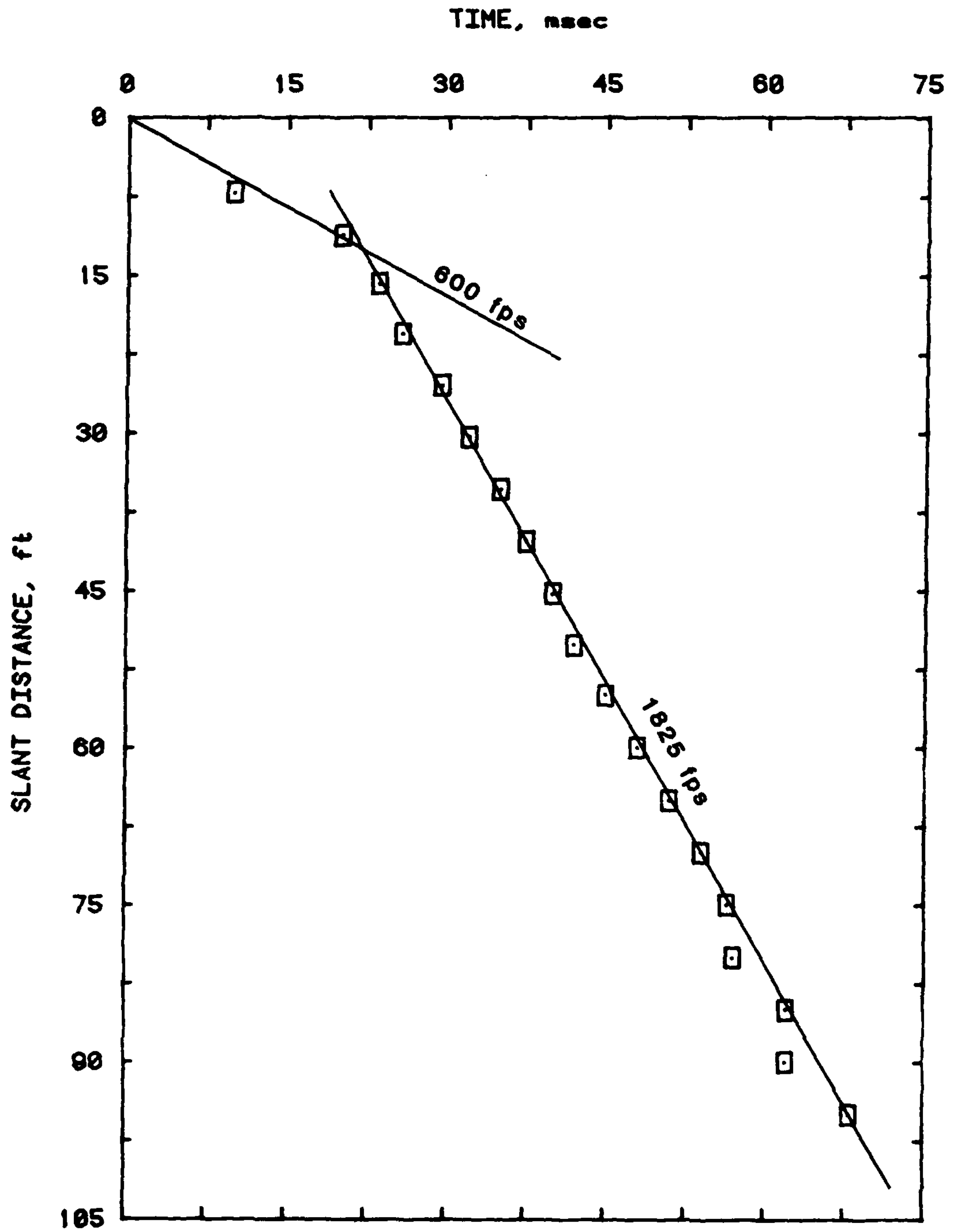


Figure 13. Downhole S-wave test conducted in borehole E, downstream toe of dam

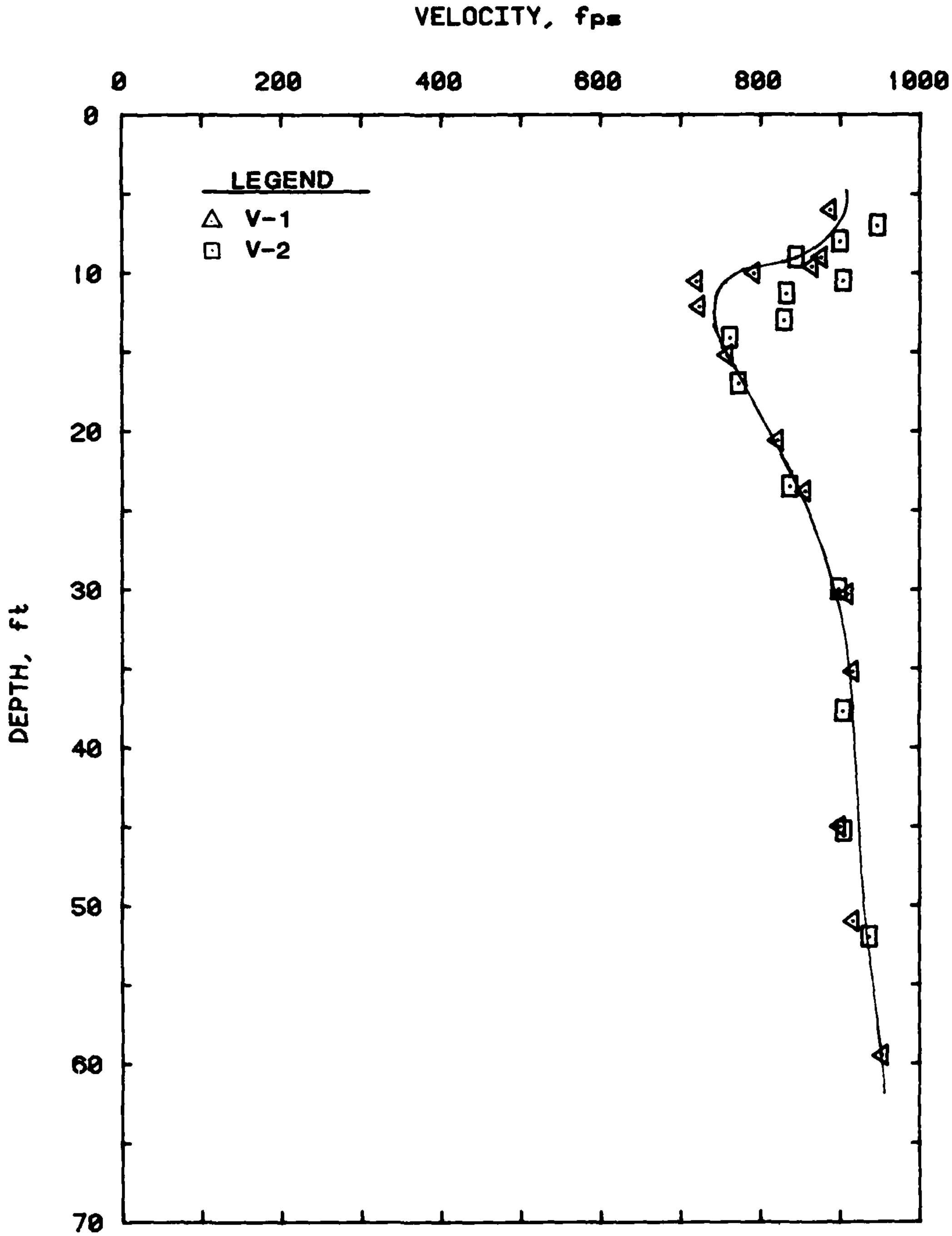


Figure 14. R-wave velocity versus depth for lines V-1 and V-2, crest of dam

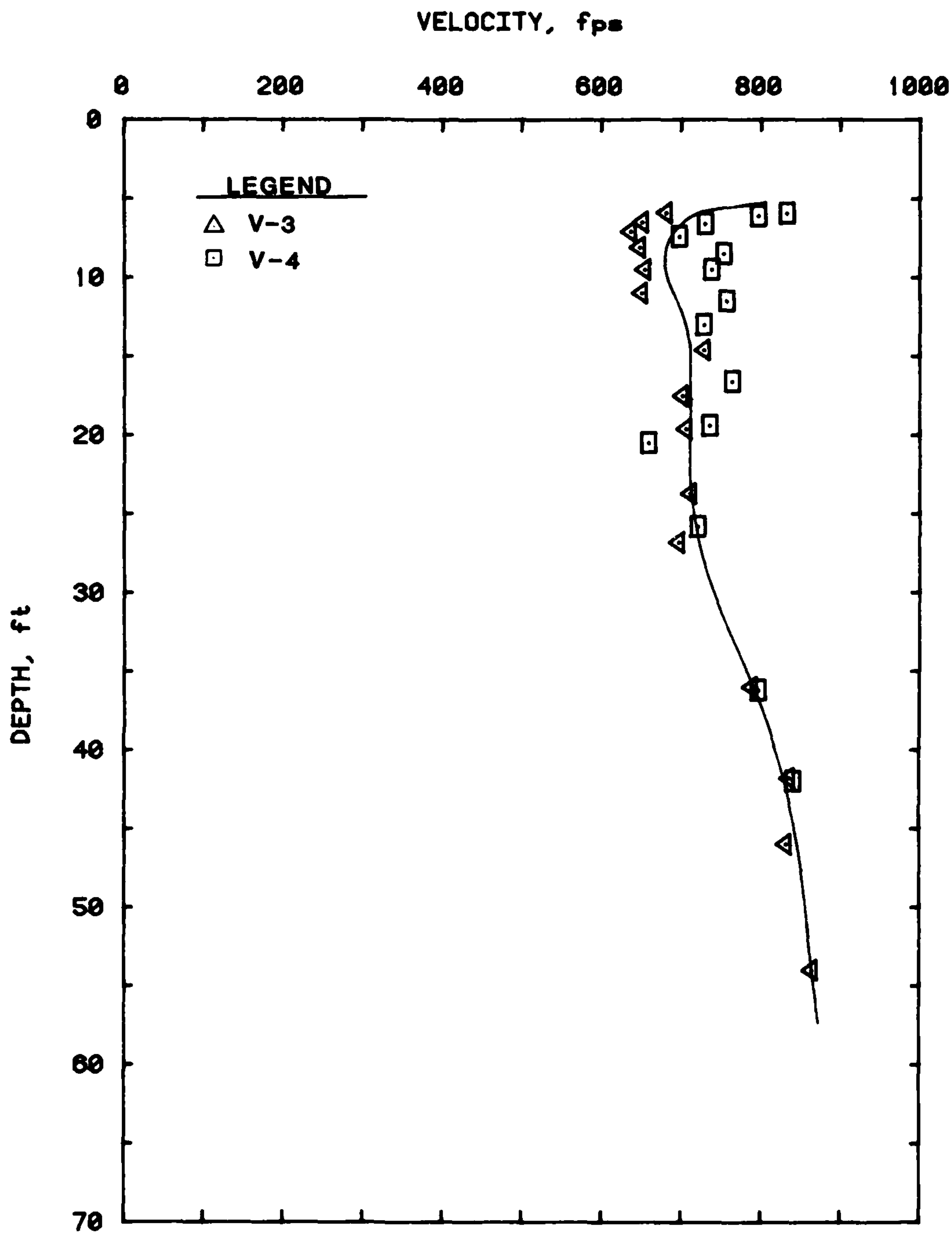


Figure 15. R-wave velocity versus depth for lines V-3 and V-4, crest of dam

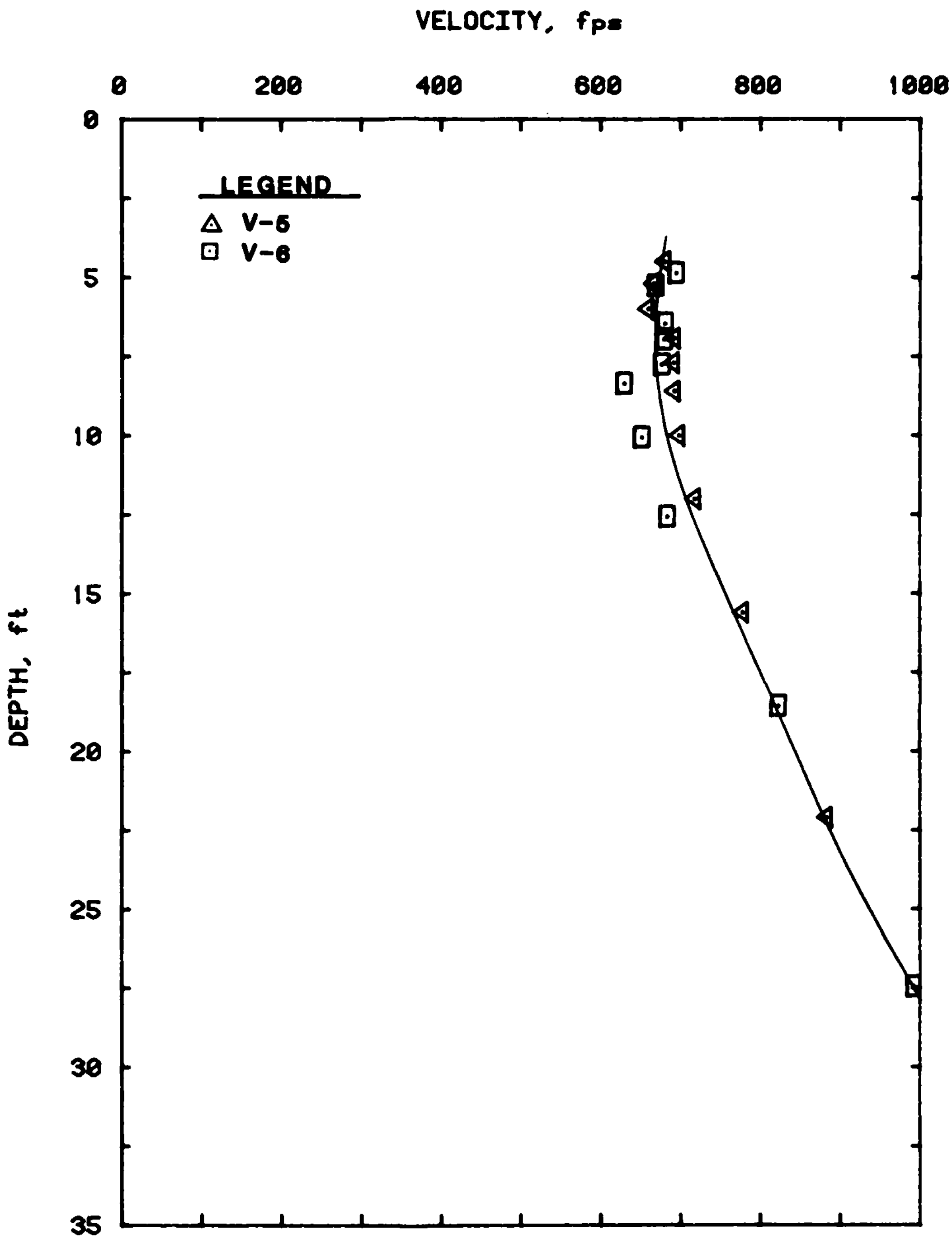


Figure 16. R-wave velocity versus depth for lines V-5 and V-6, downstream toe of dam

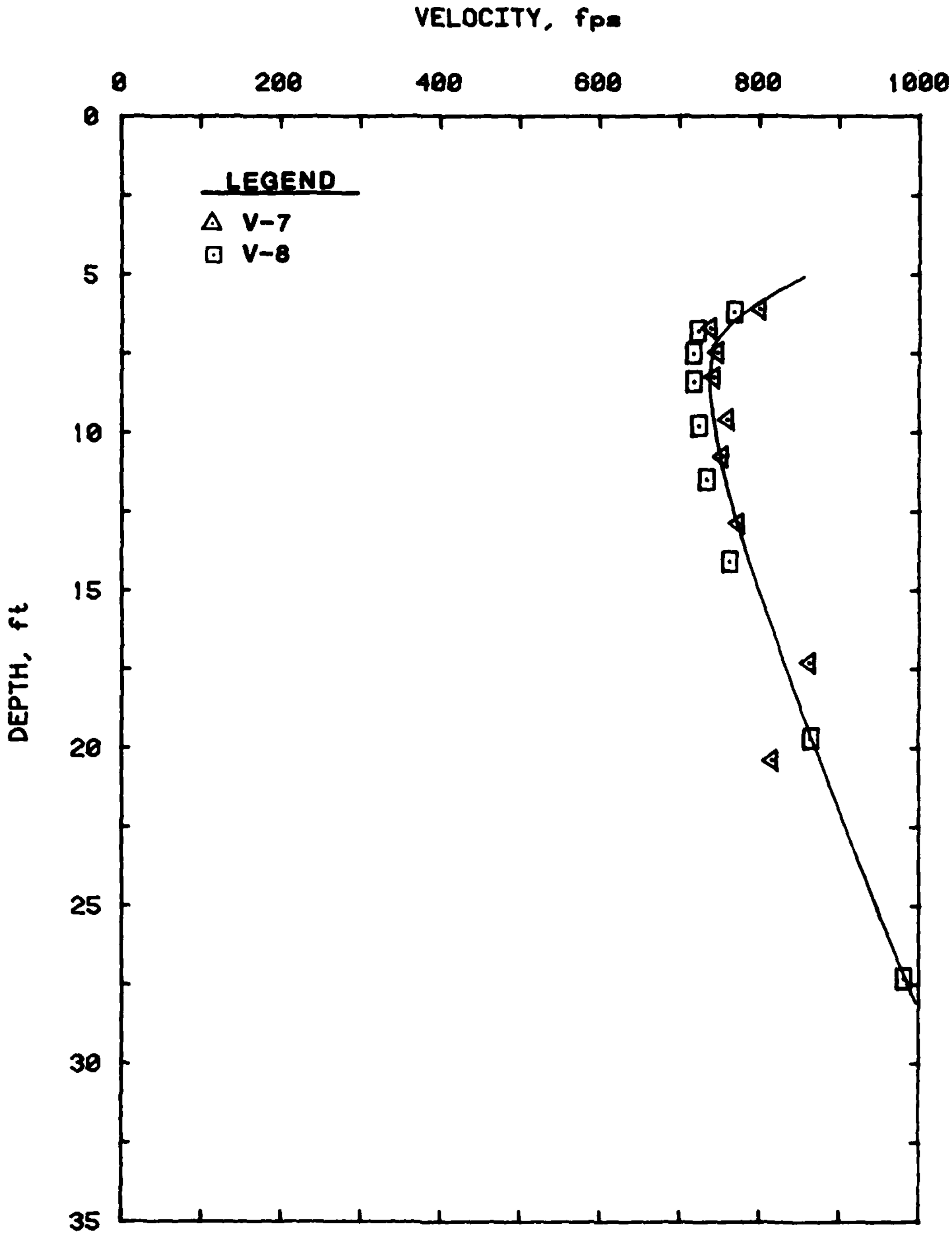


Figure 17. R-wave velocity versus depth for lines V-7 and V-8, downstream toe of dam

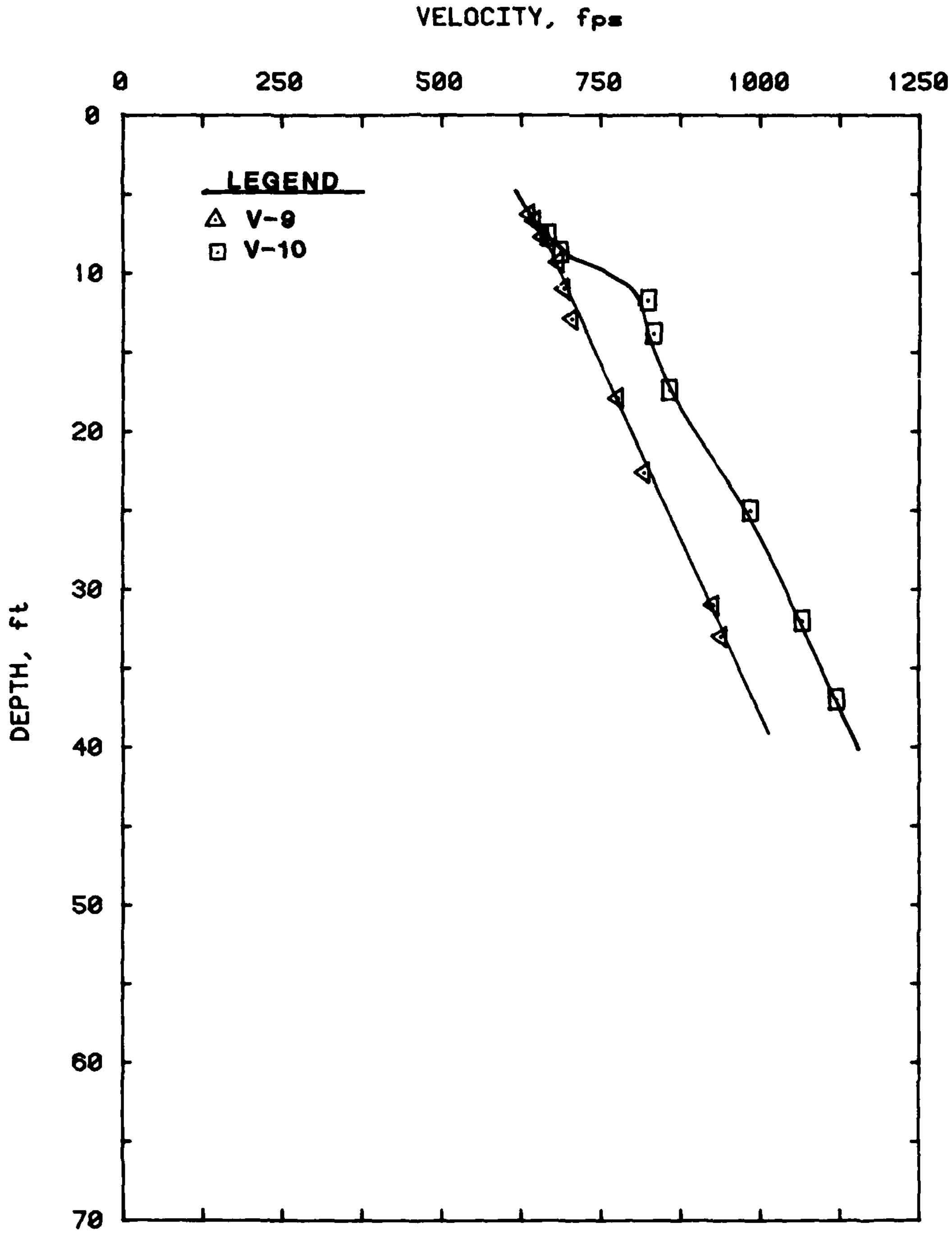


Figure 18. R-wave velocity versus depth for lines V-9 and V-10, right abutment of dam

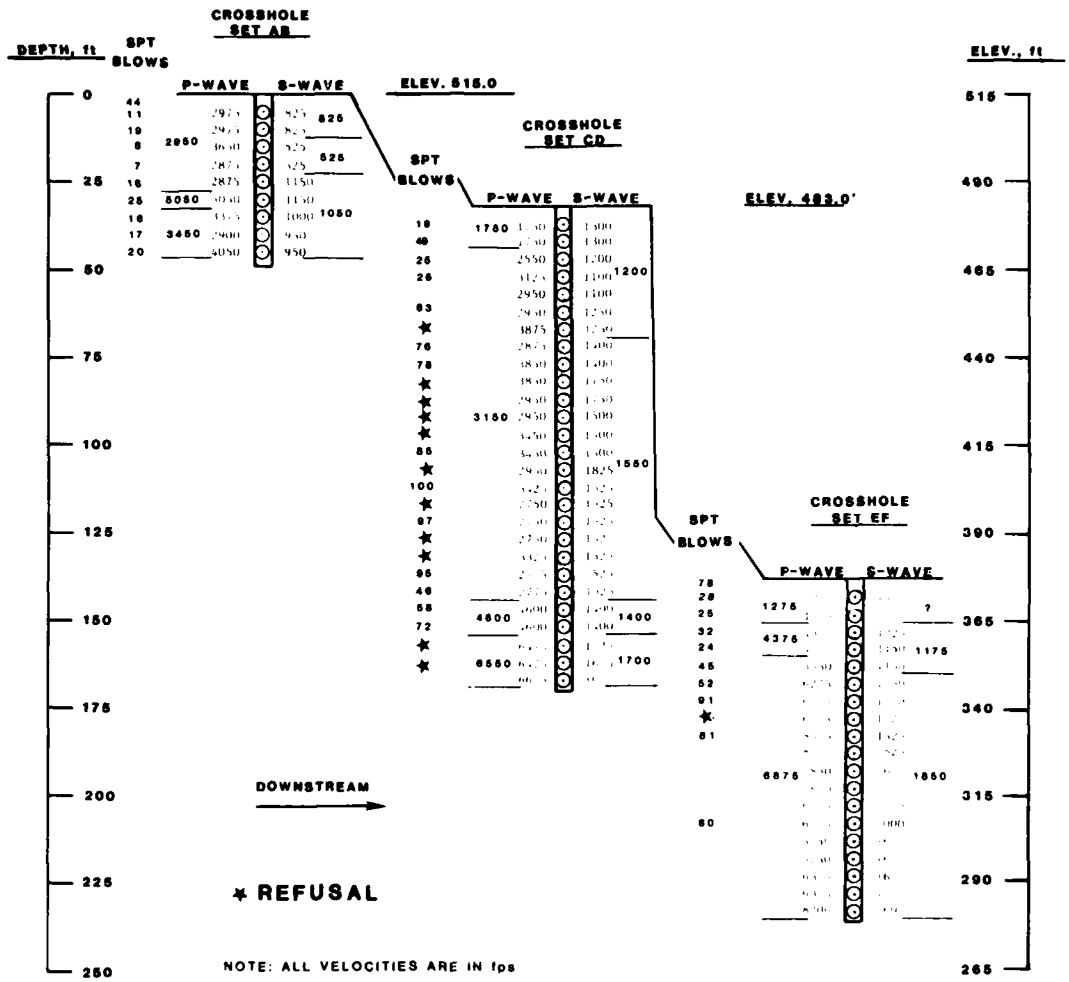


Figure 19. Crosshole results for cross sections through approximate sta 21+00

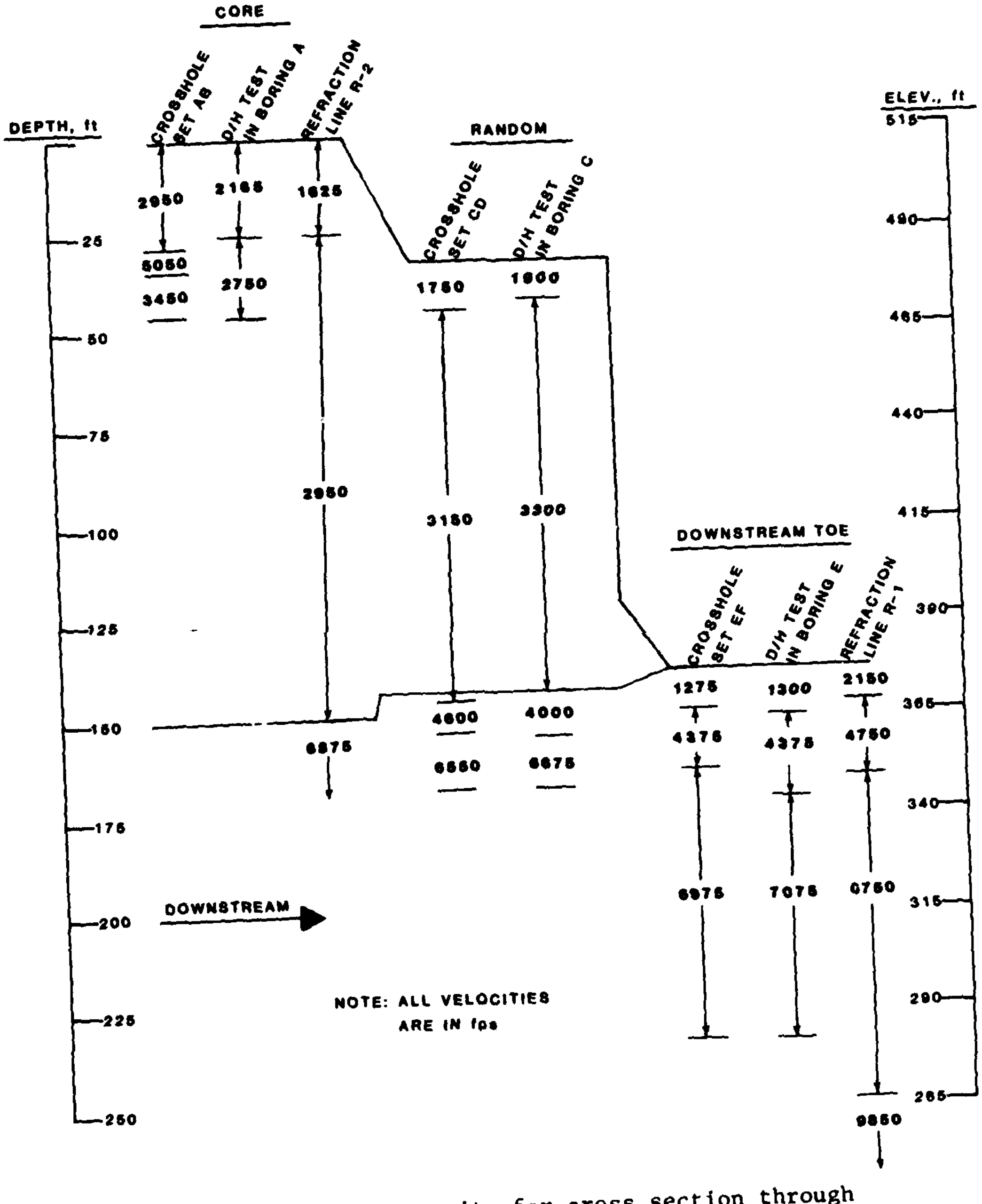


Figure 20. P-wave composite for cross section through approximate sta 21+00

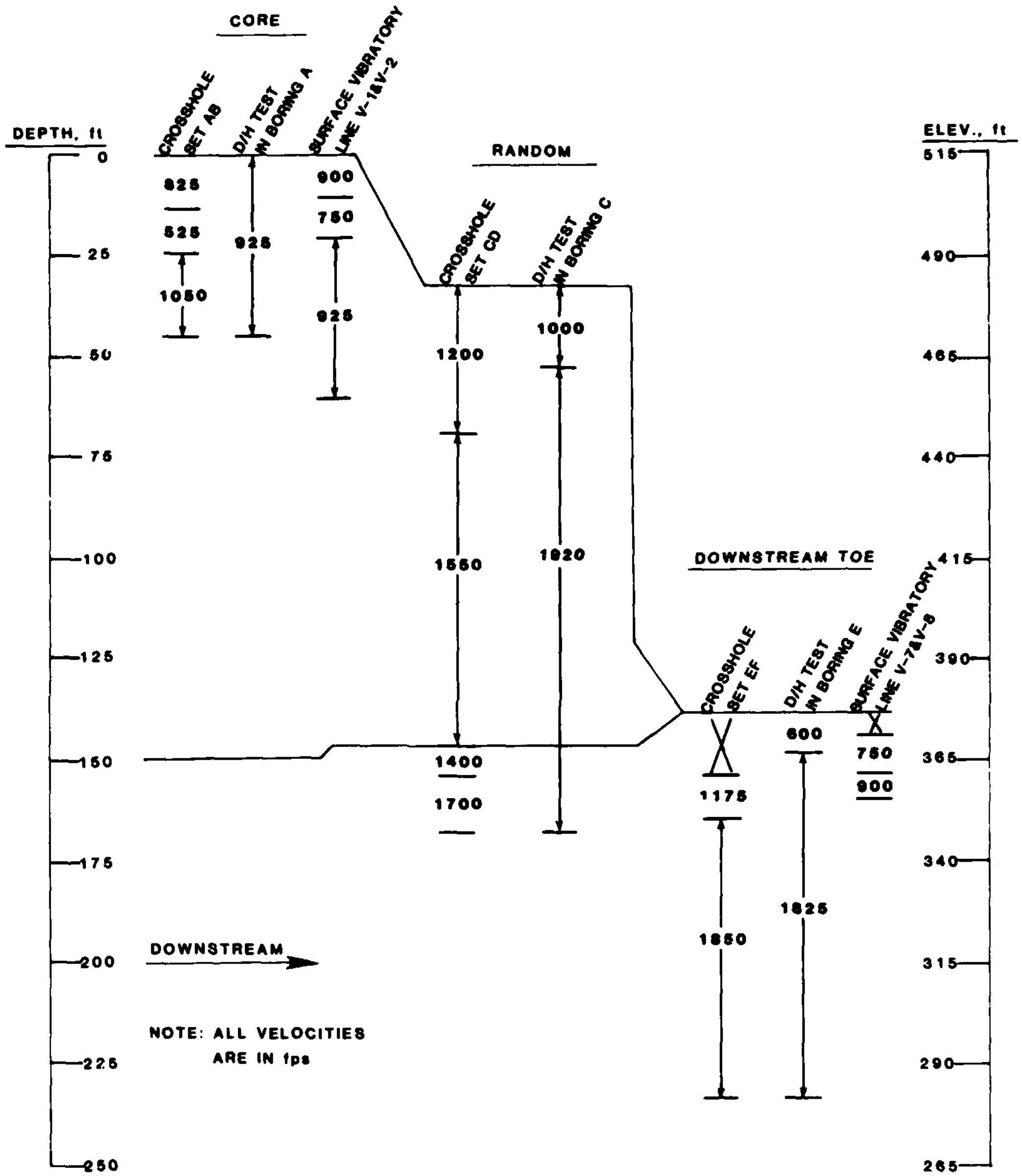


Figure 21. S-wave composite for cross section through approximate sta 21+00

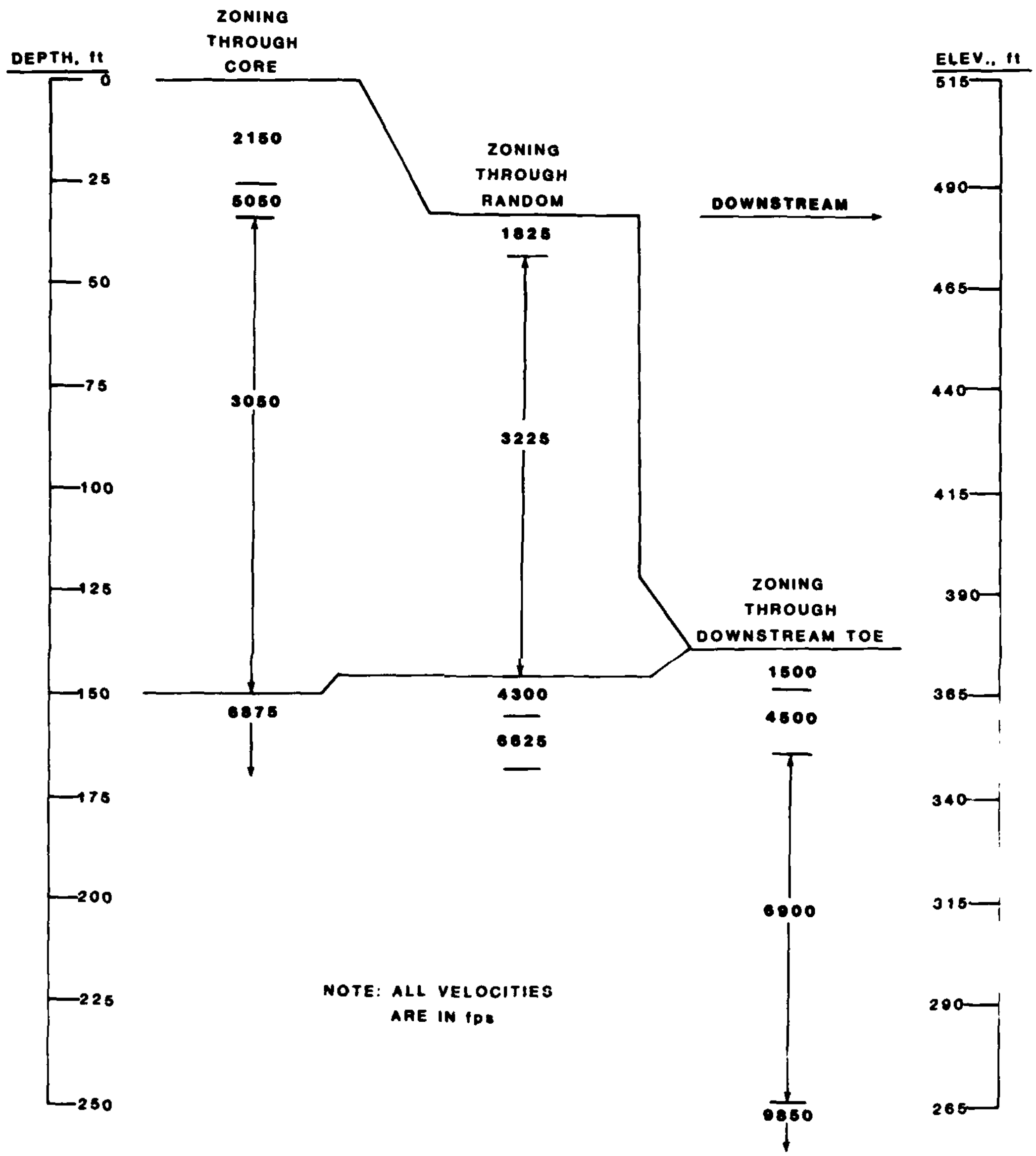


Figure 22. P-wave zonal velocity interpretation for cross section through approximate sta 21+00

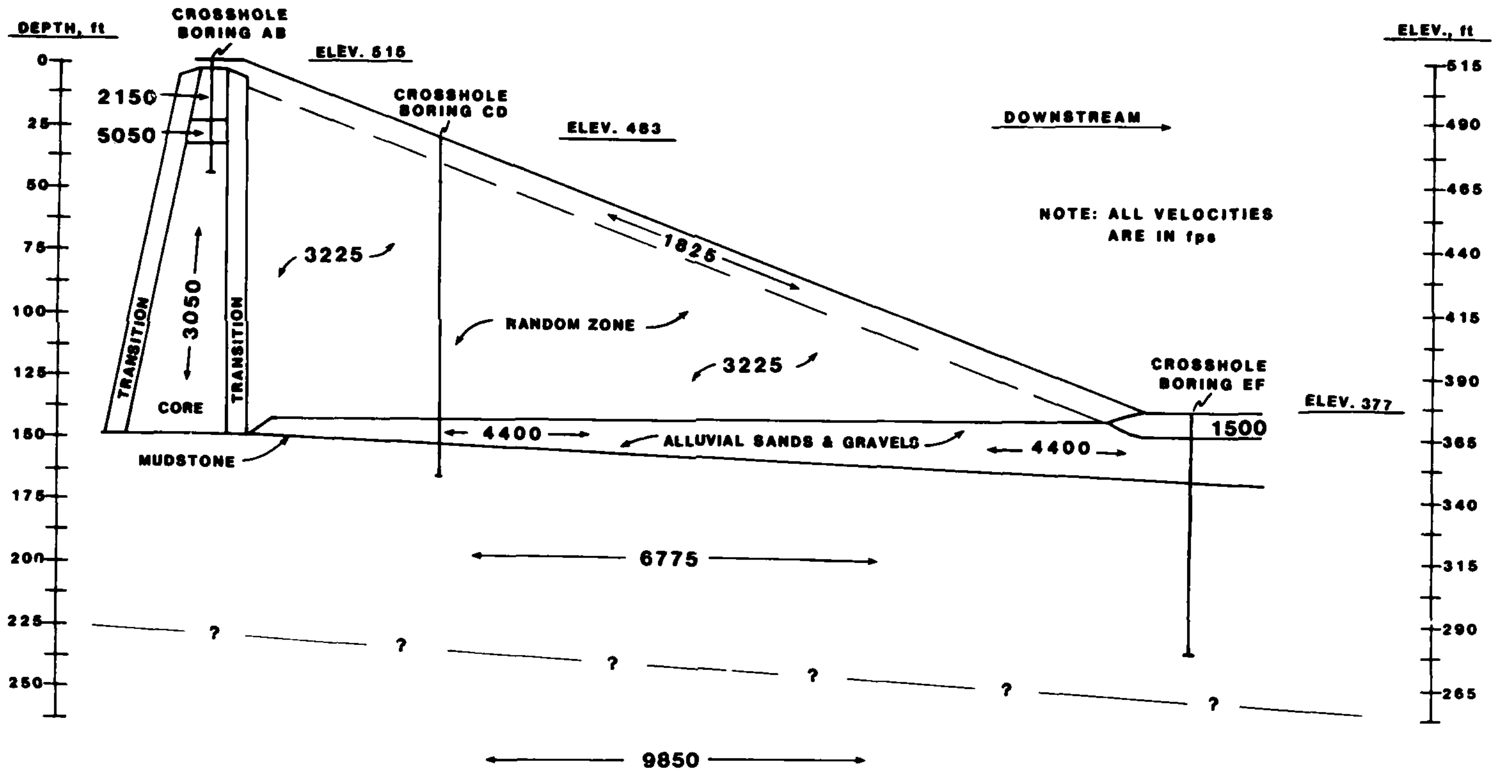


Figure 23. P-wave velocity contours for cross section at approximate sta 21+00

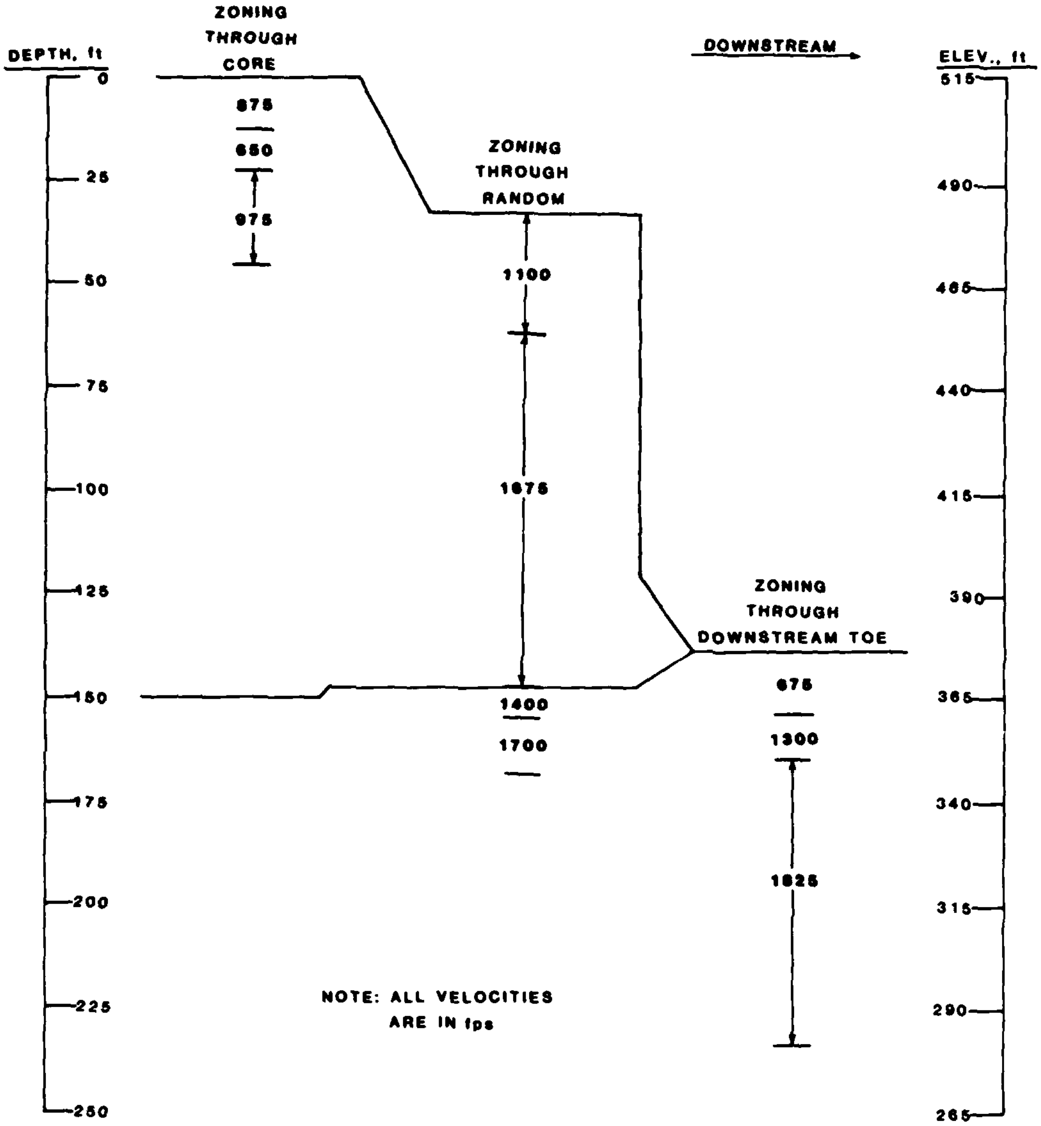


Figure 24. S-wave zonal velocity interpretation through cross section at approximate sta 21+00

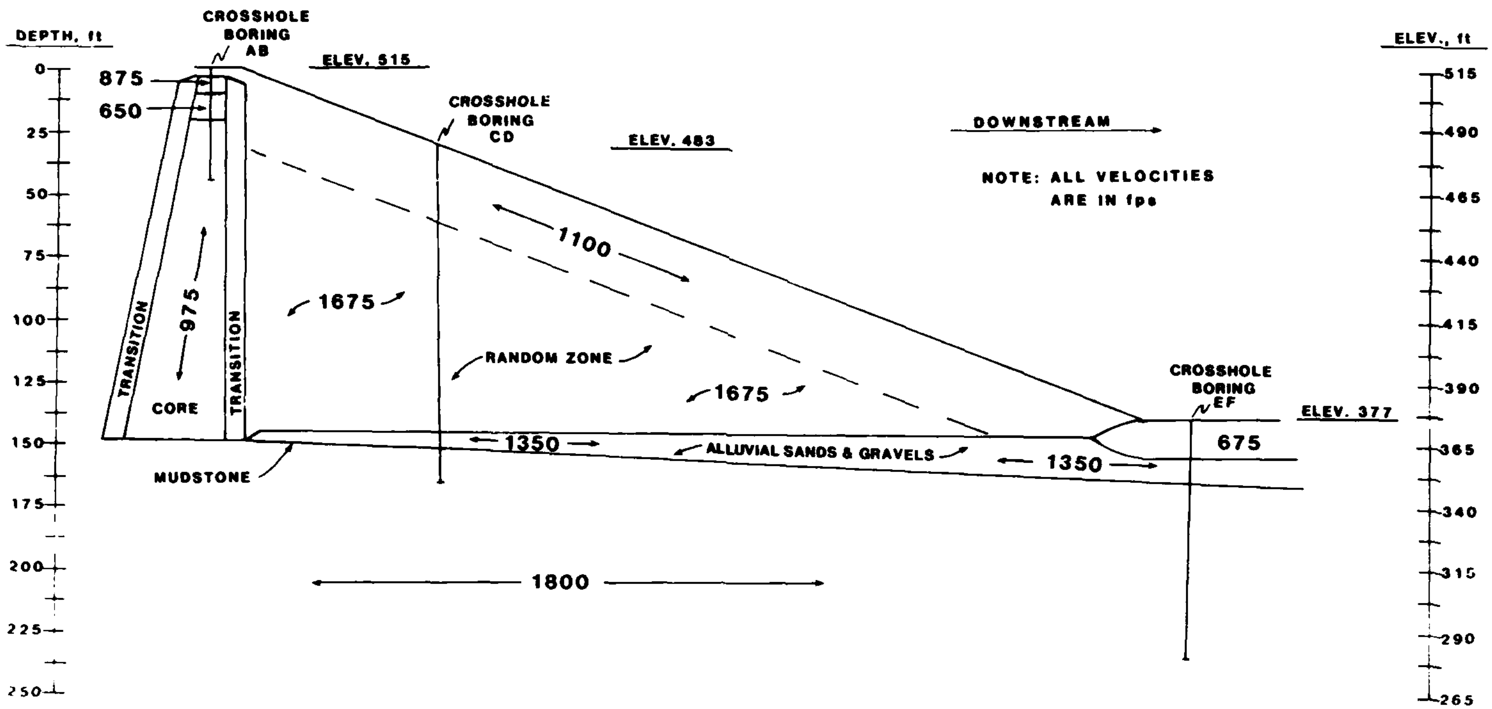


Figure 25. S-wave velocity contours for cross section at approximate sta 21+00

APPENDIX A: BORING LOG FIELD DATA

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 6 OCT 81
Location CREST Job No. ______
Drill Rig CE 4522 Inspector GLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-2 "A"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
	6 OCT	0		0	1.0			—			ROCK BIT 6 3/4" THROUGH PAVEMENT TO
											START SPLITSPOON AT 1.0'
1	6 OCT			1.0	1.5	1.4	2.5'	SPLITSPOON	JAR	13	HARD-GRAY SANDY SOIL WITH 3/4" GRAVEL
				1.5	2.0					21	
				2.0	2.5'					23	
	6 OCT		4.5'	2.5	4.5'			—			ROCK BIT 6 3/4" - HEAVY GRAVEL
2	6 OCT	4.5		4.5'	5.0	4.8	6.0	SPLITSPOON	JAR	4	TOP 0.5' TAN SANDY CLAY
				5.0	5.5'					4	BOTTOM 0.7' BLUE SANDY CLAY WITH
				5.5'	6.0					7	GRAVEL, MEDIUM STIFFNESS
3	6 OCT			6.0	6.5'	6.0	6.5'	SPLITSPOON	JAR	5	TAN & BLUE SANDY CLAY, MED. STIFFNESS
				6.5	7.0					5	
				7.0	7.5'					6	

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Sheet 1 of 5 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 6OCT81
Location CREST Job No. ______
Drill Rig CE 4522 Inspector GLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-2 "A"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
4	6OCT			7.5	8.0	7.5	7.9	SPLITSPOON	JAR	4	TAN & BLUE SANDY CLAY WITH ROCKS
				8.0	8.5					5	MED. STIFFNESS
				8.5	9.0					12	
				9.0	10.0			—			ROCK BIT 6¾" - HEAVY GRAVEL - NO SAMPLE
5	6OCT			10.0	10.5	10.2	11.5	SPLITSPOON	JAR	5	TAN SANDY CLAY MED. STIFFNESS
				10.5	11.0					5	
				11.0	11.5					14	
	6OCT			11.5	13.0						ROCK BIT 6¾" - HEAVY GRAVEL - NO SAMPLE
6	7OCT			13.0	13.5	13.2	14.5	SPLITSPOON	JAR	3	TAN-BLUE SANDY CLAY WITH FEW
				13.5	14.0					4	GRAVEL MED. STIFFNESS
				14.0	14.5					4	

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 7 OCT 81
Location CREST Job No. ______
Drill Rig CE4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-2 "A"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#7	7 OCT			14.5	15.0	14.8	16.0	SPLITSPOON	JAR	4	TAN-BLUE SANDY CLAY, MED. STIFFNESS
				15.0	15.5					4	
				15.5	16.0					6	
#8	7 OCT			16.0	16.5	16.2	17.5	SPLITSPOON	JAR	4	TAN-BLUE SANDY CLAY, MED. STIFFNESS
				16.5	17.0					6	
				17.0	17.5					11	
#9	7 OCT			17.5	18.0	17.5	18.0	SPLITSPOON	JAR	4	
				18.0	18.5					7	TAN-BLUE SANDY CLAY, MED. STIFFNESS
				18.5	19.0					8	
#10	7 OCT			19.0	19.5	19.0	19.4	SPLITSPOON	JAR	3	TAN SANDY CLAY WITH GRAVEL
				19.5	20.0					3	SOFT
				20.0	20.5					4	

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Sheet 3 of 5 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 7 OCT 81
Location CREST Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-2 "A"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#11	7 OCT			24.0	24.5	24.0	24.2	SPLITSPOON	JAR	10	TAN SANDY CLAY WITH SMALL ROCKS
				24.5	25.0					9	
				25.0	25.5'					9	
#12	7 OCT			29.0	29.5	29.4	30.5'	SPLITSPOON	JAR	9	TAN-BLUE SANDY CLAY - HARD
				29.5	30.0					10	
				30.0	30.5'					15	
#13	7 OCT			34.0	34.5'	34.2	35.5'	SPLITSPOON	JAR	4	TAN-BLUE SANDY CLAY - SOME ROCKS
				34.5	35.0					6	HARD
				35.0	35.5					10	
#14	7 OCT			39.0	39.5'	39.7	40.5'	SPLITSPOON	JAR	6	TAN-BLUE SANDY CLAY, HARD
				39.5	40.0					9	
				40.0	40.5					8	

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Sheet 4 of 5 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 7OCT81
Location CREST Job No. ______
Drill Rig CE4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-2 "A"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#15	7OCT			44.0	44.5	44.0	44.2	SPLITSPOON	JAR	5	TAN BLUE SANDY CLAY
				44.5	45.0					8	MED. STIFFNESS
				45.0	45.5					12	
#16	7OCT			49.0	49.5	49.0	49.7	SPLITSPOON	JAR	5	TAN-BLUE SANDY CLAY
				49.5	50.0					8	MED STIFFNESS
				50.0	50.5					13	

* GROUTED WITH 1 PART CEMENT - 1 PART GEL W/WATER. GROUTING WAS DONE AFTER 4" I.D. PVC CASING WAS SET W/CAP ON BOTTOM OF PIPE. CHECKED W 3 3/8 STEEL INST. GROUTED FROM 0' to 50'.

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Sheet 5 of 5 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 8 OCT 81
Location CREST Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. US-2 "B"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	CONTAINER	CLASSIFICATION AND REMARKS
*	8 OCT	0		0	4.0			—			ROCK BIT 6 3/4" HEAVY ROCK - NO SAMPLE
			4.0								
1	8 OCT	4.0		4.0	6.4	4.2	6.4	5"x6 1/4 BARREL	JAR	5" TUBE	TAN-BLUE MED. SANDY CL WITH GRAVEL
2	8 OCT			9.0	11.4	9.1	11.4	5"x6 1/4 BARREL	JAR	5" TUBE	TAN-SANDY CL, STIFF, SOME GRAVEL
3	8 OCT			14.0	16.4	14.0	15.0	5"x6 1/4 BARREL	JAR	5" TUBE	TAN-BLUE SANDY CL, MED.
4	8 OCT			19.0	21.4	19.0	19.7	5"x6 1/4 BARREL	JAR	5" TUBE	TAN SANDY CL MED.
5	8 OCT			24.0	26.4	24.4	26.4	5"x6 1/4 BARREL	JAR	5" TUBE	TAN-BLUE SANDY CL, MED, GRAVEL
6	8 OCT			29.0	31.4	29.0	29.6	5"x6 1/4 BARREL	JAR	5" TUBE	TAN-BLUE SANDY CL, MED, GRAVEL
7	9 OCT			34.0	36.4	34.2	36.4	5"x6 1/4 BARREL	JAR	5" TUBE	TAN BLUE SANDY CL, MED, GRAVEL
8	9 OCT			39.0	41.4	39.4	41.4	5"x6 1/4 BARREL	JAR	5" TUBE	BLUE SANDY CL MED

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 2 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ____ Date 9OCT81
Location CREST Job No. ____
Drill Rig CE4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ____ Boring No. US-2 "B"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	CONTAINER	CLASSIFICATION AND REMARKS
9	9 OCT			44.0	46.4	44.4	46.4	5"X6¼ BARREL	JAR	5"TUBE	TAN BLUE SANDY CL MED, GRAVEL
10	9OCT			49.0	51.4	50.0	51.4	5"X6¼ BARREL	JAR	5"TUBE	BLUE SANDY CL STIFF, GRAVEL

* GROUTED WITH 1PART CEMENT TO 1 PART GEL W/WATER. GROUTING WAS DONE AFTER 4" I.D PVC CASING WAS SET W/CAP ON BOTTOM OF PVC. CHECKED WITH 3⅞ STEEL INST. GROUTED 0' to 50'.

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 2 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ____ Date 26 NOV 81
Location 10 ft South of SS3 DOWNSTREAM Slope Job No. ____
Drill Rig SKID Inspector TOH Operator STEWART Surface El ____ Boring No. USSR "C"

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
	26 NOV			0.0	10.0			6 3/4" Rock Bit			Clean Out Hole
	26 NOV			0.0	10.0			8" Rock Bit			Clean Out Hole
	26 NOV			10.0	13.0			6 3/4" Rock Bit			Clean Out Hole - Lost Bit
											AND GUIDE IN Hole - ROD SNAPPED
											FISHED OUT BIT AND DISCOVERED
											large VOID Due to FALL IN of
											loose GRAVEL FROM THE WALL.
											VOID begins JUST UNDER THE
											4 Ft THICK CONCRETE base
											USED AS guide hole.
	27 NOV										GROUT Hole w/HARD GROUT
											2 bbls GROUT USED TO FILL VOID
											AND Hole UP TO CONCRETE base

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 28 NOV 81
Location 10 ft SOUTH OF SS-3 DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. USSA "C"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	28 NOV			4.0	35.0			$6\frac{3}{4}$" Rock Bit			Clean out Hole of Grout
											Then Drill to 35.0 ft
	28 NOV										Grout Hole w/soft Grout
											$1\frac{1}{2}$ bbls Grout Used
	30 NOV			35.0	57.0			$6\frac{3}{4}$" Rock Bit			Clean Out Hole
	1 DEC			57.0	87.0			$6\frac{3}{4}$" Rock Bit			Clean Out Hole
	2 DEC			87.0	120.0			$6\frac{3}{4}$" Rock Bit			Clean out Hole
											Foundation Bedrock @ 116.0'
											Appears to be Siltstone-Clay with
											large Rocks intermixed by drill
											effect to 120.0'
	3 DEC			120.0	121.0			$6\frac{3}{4}$" Rock Bit			Clean Out Hole

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 2 of 4 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 3 DEC 81
Location 10 ft SOUTH OF SS3 DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. US3A "C"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
1	3 DEC			121.0	123.0	123.0	123.0	5X6¼			NO SAMPLE RECOVERED. SEVERAL
											TEETH OF BIT WERE DESTROYED
											AND/or BROKEN OFF
	3 DEC			123.0	125.0			6¾" RockBit			CLEAN OUT HOLE
2	3 DEC			125.0	126.8	125.0	125.9	5X6¼		TUBE	CLAYEY SILTSTONE - DARK to LIGHT
2A						125.9	126.8	CORE BARREL		JAR	GREEN COLOR - VERY COHESIVE
											LITTLE MOISTURE - SOMEWHAT BRITTLE
	4 DEC			126.0	130.0			6¾ Rock BIT			CLEAN out Hole
3	4 DEC			130.0	131.7	130.3	131.6	5X6¼		TUBE	CLAYEY SILTSTONE - DARK, GREEN
3A						131.6	131.7	CORE BARREL		JAR	VERY COHESIVE - LITTLE MOISTURE
											Somewhat Brittle
	4 DEC			131.7	135.5			6¾" RockBit			CLEAN OUT Hole

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 3 of 4 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 4 DEC 81
Location 10 ft SOUTH OF SS3 DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. US3A

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
4	4 DEC			135.5	138.0	135.7	137.7	5X6 1/4		TUBE	CLAYEY SILTSTONE - DARK GREEN
4A						137.7	138.0	Core Barrel		JAR	VERY COHESIVE - LITTLE MOISTURE
											BRITTLE
5	4 DEC			138.0	140.0	138.0	140.4	5X6 1/4		TUBE	CLAYEY SILTSTONE - DARK GREEN
5A						140.4	140.5	CORE Barrel		JAR	VERY COHESIVE - LITTLE MOISTURE
											Brittle
	4 DEC										4-in PVC Casing Grouted in PLACE
											10 1/2 Barrel HARD GROUT FROM
											140.5' to 116.0'
	5 DEC										Soft GROUT, 3 1/2 BBL FROM
											116.0' to 0.0 ft.

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 4 of 4 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 21 OCT 81

Location DOWNSTREAM SLOPE Job No. ______

Drill Rig ______ Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
	ROCK	BIT	WITH	6 3/4"	THRU	5.5'	RIP RAP				
#1	21 NOV	5.5		5.5	6.0			SPLITSPOON	JAR	4	TAN-SANDY CL MED.
				6.0	6.5					9	
				6.5	7.0					10	
#2	21 NOV			10.0	10.5'	10.7	11.5'	SPLITSPOON	JAR	15	TAN-GRAY SANDY CL MED.
				10.5	11.0					23	
				11.0	11.5'					26	
#3	21 NOV			15.0	15.5'	16.0	16.5'	SPLITSPOON	JAR	5	TAN-GRAY SANDY CL MED.
				15.5	16.0					9	FEW GRAVEL
				16.0	16.5'					16	
#4	21 NOV			20.0	20.5'	21.2	21.5'	SPLITSPOON	JAR	3	TAN SANDY CL MED.
				20.5	21.0					9	
			21.5	21.0	21.5					16	

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 1 of 10 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 21 OCT 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig ______ Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
	ROCK BIT (6 3/4") TO 28.0' LARGE AMOUNT OF PEA GRAVEL COMING FROM HOLE.										
	THEY ARE BELIEVED COMING FROM A CAVITY APPROX. 6' DOWN. GROUTED HOLE WITH										
	CEMENT-GEL MIXTURE USING CALCIUM CHLORIDE TO ACCELERATE SET 22 OCT 81										
	USED 1½ BAGS CEMENT & 1½ BAGS GEL MIXED WITH WATER. THIS FILLED HOLE TO										
	7.0', ON 23 OCT 81 USED 2 BAGS CEMENT & 2 BAGS GEL - CALCIUM CHLORIDE MIXED										
	WITH WATER. THIS FILLED HOLE & CAVITY.										
#5	24 OCT	21.5'		28.0	28.5'	28.5'	29.5'	SPLITSPOON	JAR	33	COARSE GRAY SAND - STIFF
				28.5'	29.0					33	ABOUT 0.2' TAN CL AT BOTTOM
				29.0	29.5'					30	OF SAMPLE
#6	26 OCT			35.0	35.5'	35.3	35.9	SPLITSPOON	JAR	20	COARSE GRAY SAND-STIFF
				35.5'	35.9					50	
	GROUTED TO A DEPTH OF 40' WITH CEMENT/WATER CALCIUM CHLORIDE. GROUT										
	USED 5-55 GAL OR 250 GAL TO FILL HOLE. 9 BAG CEMENT USED. THIS WAS										
	DONE BECAUSE OF FAILURE OF CEMENT-GEL MIXTURE.										

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 27 OCT 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig ______ Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
	27 OCT	ROCK BIT		BACK TO 20'	THROUGH			CONCRETE	GROUT		
	28 OCT	ROCK BIT		TO 40'	THROUGH	CONCRETE		GROUT			
#7	28 OCT			40.0	40.5	40.5	41.5	SPLITSPOON	JAR	19	COARSE GRAY SAND w/FEW 3/4"
				40.5	41.0					33	GRAVEL - STIFF
				41.0	41.5					43	
#8	28 OCT			45.0	45.5	45.3	46.5	SPLITSPOON	JAR	25	COARSE GRAY SAND W/FEW GRAVEL
				45.5	46.0					33	STIFF - SMALL AMOUNT OF
				46.0	46.5					45	TAN CL.
#9	28 OCT			51.0	51.5	51.1	51.8	SPLITSPOON	JAR	50	COARSE TAN/GRAY SAND - STIFF
				51.5	51.8					50	
#10	28 OCT			55.0	55.5	55.1	56.0	SPLITSPOON	JAR	25	COARSE TAN/GRAY SAND - STIFF
				55.5	56.0					50	SOME GRAVEL

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 29 OCT 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig ______ Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#11	29 OCT			60.0	60.5	60.0	61.0	SPLITSPOON	JAR	35	TAN-GRAY COARSE SAND-STIFF
				60.5	61.0					50	
#12	29 OCT			65.0	65.5	65.5	65.9	SPLITSPOON	JAR	34	TAN-GRAY COARSE SAND-STIFF
				65.5	65.9					50	
#13	29 OCT			70.0	70.5	70.2	71.4	SPLITSPOON	JAR	20	TAN-GRAY COARSE SAND-MED
				70.5	71.0					35	LARGE GRAVEL IN BOTTOM OF SS
				71.0	71.4					50	GAVE HIGH LAST READING, TRACE OF CL
#14	30 OCT			75.0	75.5	75.6	75.9	SPLITSPOON	JAR	40	GRAY COARSE SAND-MED
				75.5	75.9					60	LARGE GRAVEL GAVE HIGH READING
#15	30 OCT			80.0	80.5	80.2	81.3	SPLITSPOON	JAR	30	TAN-GRAY COARSE SAND-STIFF
				80.5	81.0					50	FEW 1/2" GRAVEL
				81.0	81.3					50	

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 4 of 10 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE Site ______ Date 30 OCT 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig ______ Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#16	30 OCT			85.0	85.5'	85.2	86.0	SPLITSPOON	JAR	35	GRAY COARSE SAND-MED.
				85.5'	86.0					50	
#17	31 OCT			90.6	90.5'	90.3	91.4	SPLITSPOON	JAR	25'	GRAY COARSE SAND-MED.
				90.5'	91.0					46	
				91.0	91.4					51	
#18	31 OCT			95.0	95.5'	95.1	95.9	SPLITSPOON	JAR	40	GRAY COARSE SAND-STIFF
				95.5'	95.9					60	
	4 NOV			40.0	100.0			6 3/4" ROCK BIT			CLEAN OUT HOLE-HIT FOUNDATION @ 99.0'
#19	5 NOV			100.0	100.9	100.2	100.9	SPLITSPOON	JAR	25	GRAY SANDY ML-FINE TO MED, GRAY
										51	GRAVEL 3/4" MAX-LITTLE MOISTURE COHESION
											SMALL PCS RED GRAVEL NOTED
	6 NOV			100.9	105.0			6 3/4" ROCK BIT			CLEAN OUT HOLE

Sheet 5 of 10 Sheets

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 6 NOV 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#20	6 NOV			105.0	106.5	105.5	106.5	SPLITSPOON	JAR	27	SAND-GRAY: FINE to MED 30%
										45	GRAVEL-GRAY, White 3/4" MAX
										50	GOOD CONSOLIDATION, little MOISTURE
											GROUT Hole from 106.5 ft to 41.5 ft
											120 GAL the. / 3.5 bbls ACTUAL
											1:1 Cmt/Gel w/c = 3.2 ?
	9 NOV			41.5	106.5			6 3/4" ROCK BIT			REAM OUT Hole 41.5 to 106.5 ft
#21	9 NOV			106.5	107.3	106.5	107.3	SPLITSPOON	JAR	40	106.5 to 106.9 CLAY w/GRAVEL
										50	3/4" GRAY, dense, MOIST
											106.9 to 107.3 SANDY GRAVEL
											FINE to MED SAND, GRAD.-GRAVEL
											1/2" MAX GRAY w/ some white pcs
											FAIR CONSOLIDATION, little MOISTURE
	9 NOV			107.3	108.0			6 3/4" ROCK BIT			CLEAN OUT Hole

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site Date 9 NOV 81
Location DOWNSTREAM SLOPE Job No.
Drill Rig SKID Inspector TOM Operator STEWART Surface El Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#22	9 NOV			108.0	109.0	108.0	109.0	SPLITSPOON	JAR	50	CLAYEY SAND GRAVEL - SAND, V
										50	FINE, GRAY - GRAVEL 3/4" MAX
											w/ white pcs INTERMIXED
											CLAY base, very cohesive,
											FAIR MOISTURE
	9 NOV			109.0	109.5			6 3/4" ROCK BIT			CLEAN OUT HOLE
#23	9 NOV			109.5	111.0	110.0	111.0	SPLITSPOON	JAR	20	CLAYEY SAND GRAVEL - SAND GRAY,
										24	FINE, GRAVEL 1 1/4" MAX WHITE
										22	Rock w/ gray gravel pcs
											CLAY base, gray, little cohesion
											little MOISTURE.
	10 NOV			111.0	114.0			6 3/4" ROCK BIT			CLEAN OUT HOLE

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 7 of 10 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ____ Date 10 NOV 81
Location DOWNSTREAM SLOPE Job No. ____
Drill Rig SKID Inspector TOM Operator STEWART Surface El ____ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
#24	10 NOV			114.0	115.5	114.1	115.5	SPLITSPOON	JAR	27	SAND-MED to COARSE GRAY
										33	GRAVEL 1¼" MAX GRAY & WHITE
										25	LITTLE MOISTURE, NO COHESION
	10 NOV			115.5	118.0			6¾" ROCK BIT			CLEAN OUT HOLE
											116.0 to 117.0 SOLID ROCK
											CLAY-MUDSTONE @ 117.0 ft
#25	10 NOV			118.0	119.5	118.1	119.5	SPLITSPOON	JAR	16	CLAY-MUDSTONE-GRAYISH GREEN
									1.3 ft	27	TO GREEN, HIGH COHESION, LITTLE
										45	MOISTURE.
	10 NOV			119.5	121.0			6¾" ROCK BIT			CLEAN OUT HOLE
#26	10 NOV			121.0	122.4	121.0	122.4	SPLITSPOON	JAR	17	0.2 ft V. FINE SAND @ 121.8
									1.2 ft	28	CLAY; MUDSTONE GREEN HIGH
										50	COHESION LITTLE MOISTURE

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

Sheet 8 of 10 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 11 NOV 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	11 NOV			122.4	125.0			6 3/4" BIT			CLEAN OUT Hole
#27	11 NOV			125.0	126.0	125.0	126.0	SPLITSPOON	JAR	25	CLAY-MUDSTONE, GREEN
										50	DENSE SOLID 1ft PIECE
	11 NOV			126.0	129.0			6 3/4" BIT			CLEAN OUT Hole
#28	11 NOV			129.0	130.0	129.0	130.0	SPLITSPOON	JAR	25	CLAY MUDSTONE, GREEN, BROWN
										53	GREENISH
	11 NOV			130.0	133.0			6 3/4" BIT			CLEAN OUT Hole
#29	11 NOV			133.0	134.0	133.0	134.0	Splitspoon	JAR	32	CLAY MUDSTONE, GREEN
										50	DENSE SOLID 1ft PIECE

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 12 NOV 81
Location DOWNSTREAM SLOPE Job No. ______
Drill Rig SKID Inspector TOM Operator STEWART Surface El ______ Boring No. SS-3 "D"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
	12 NOV			134.0	137.0			6 3/4" Rock Bit			CLEAN OUT Hole
30	12 NOV			137.0	137.8	137.0	137.8	SPLITSPOON	JAR	31	CLAY-MUDSTONE DARK GRAY
										50	SOLID DENSE .8 ft Piece
											Grout Bottom 20 ft w/STRAIGHT
											CEMENT AND WATER APPROX 1 gal
											Grout Upper 120 ft w/1:1 RATIO
											of CEMENT AND GEL w/ENOUGH
											WATER FOR A PUMPABLE MIXTURE
											APPROX 127 gal. GROUT WAS
											placed AROUND THE 4 in ID
											PVC Pipe.
											WATER LEVEL @ 98.8 ft in
											PVC Pipe.

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 18 SEPT 81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLAN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-1 "G"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
1	18SEPT	0.0		0.0	0.5	0.5	1.5	SPLITSPOON	JAR	8	GRAY SAND & GRAVEL
				0.5	1.0					34	
				1.0	1.5					44	
2	19SEPT			1.5	2.0	1.7	3.0	SPLITSPOON	JAR	20	GRAY SAND & GRAVEL
				2.0	2.5					32	
			3.0	2.5	3.0					38	
3	19SEPT	3.0		3.0	3.5	3.5	4.5	SPLITSPOON	JAR	14	GRAY SAND, FINE
				3.5	4.0					16	
			4.5	4.0	4.5					16	
4	19SEPT	4.5		4.5	5.0	5.1	6.0	SPLITSPOON	JAR	12	GRAY SAND, Coarse
				5.0	5.5					14	
				5.5	6.0					14	

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 19 SEPT 81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
5	19 SEPT			6.0	6.5	6.7	7.5	SPLITSPOON	JAR	6	GRAY SAND, Coarse
				6.5	7.0					7	
				7.0	7.5					9	
6	19 SEPT			7.5	8.0	8.3	9.0	SPLITSPOON	JAR	4	GRAY SAND, Coarse
				8.0	8.5					6	
				8.5	9.0					10	
7	19 SEPT			9.0	9.5	9.8	10.5	SPLITSPOON	JAR	6	GRAY SAND, Coarse
				9.5	10.0					10	
			10.5	10.0	10.5					15	
8	19 SEPT	10.5		10.5	11.0	11.2	12.0	SPLITSPOON	JAR	8	GRAY SAND, Coarse & 1/2" GRAVEL
				11.0	11.5					11	
			12.0	11.5	12.0					14	

WES FORM JAN 74 819 EDITION OF NOV 1971 MAY BE USED

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 19 SEPT 81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
9	19 SEPT	12.0		12.0	12.5'	12.3	13.5'	SPLITSPOON	JAR	7	BLUE-GRAY, SANDY-CLAY MED.
				12.5'	13.0					10	
				13.0	13.5'					16	
10	19 SEPT			13.5'	14.0	13.6	15.0	SPLITSPOON	JAR	9	BLUE-GRAY, SANDY-CLAY MED.
				14.0	14.5'					12	
				14.5'	15.0					20	
11	19 SEPT			15.0	15.5	15.2	16.5	SPLITSPOON	JAR	8	BLUE-GRAY, SANDY-CLAY MED
				15.5'	16.0					10	
				16.0	16.5'					20	
12	19 SEPT			16.5'	17.0	16.5	18.0	SPLITSPOON	JAR	5	BLUE-GRAY, SANDY-CLAY MED
				17.0	17.5'					8	
				17.5'	18.0					15'	

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 19SEPT 81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CE 45C2 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
13	19SEPT			18.0	18.5	18.0	19.5	SPLITSPOON	JAR	5	BLUE-GRAY, SANDY-CLAY MED.
				18.5	19.0					9	
				19.0	19.5					15	
14	19SEPT			25.0	25.5	25.0	26.5	SPLITSPOON	JAR	12	BLUE-GRAY, SANDY-CLAY MED
				25.5	26.0					22	
				26.0	26.5					23	
15	19SEPT			30.0	30.5	30.0	31.5	SPLITSPOON	JAR	10	BLUE-GRAY, SANDY-CLAY MED.
				30.5	31.0					22	
				31.0	31.5					30	
16	21SEPT			35.0	35.5	35.0	36.3	SPLITSPOON		15	BLUE-GRAY, MED. SANDY-CLAY
				35.5	36.0					41	w/ 1½" BASALT ROCK IN END OF SPOON
			36.2	36.0	36.3					50	

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Sheet 4 of 7 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 21 SEPT 81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM		DRIVE		SAMPLE		TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
		FROM	TO	FROM	TO	FROM	TO				
17	21 SEPT	36.2		40.0	40.5	40.0	40.5	SPLITSPOON	JAR	50	BLUE-GRAY CLAY WITH ROCKS MED.
18	21 SEPT			45.0	46.5	45.0	45.5	SPLITSPOON	JAR	13	BLUE-GRAY W/ROCKS MED.
						45.5	46.0			33	
						46.0	46.5			48	
			47.0								
19		47.0		50.0	55.0	50.0	54.0	3" CORE R-BARREL	CORE BOX	–	BASALT ROCK-LOST 1', BLUE-GRAY MED, 1CLAY
20				55.0	57.1	55.0	56.0	R-BARREL	CORE BOX	–	BASALT ROCK-LOST 1.1' W/CLAY BLUE-GRAY MED.
21				57.1	59.0	57.1	58.5	R-BARREL	CORE BOX	–	BASALT ROCK-LOST 0.5' W/CLAY BLUE-GRAY MED.
22				59.0	60.3	59.0	60.3	R-BARREL	CORE BOX	–	BASALT ROCK W/CLAY BLUE-GRAY MED.
23				60.3	61.5	60.3	61.5	R-BARREL	CORE BOX	–	BASALT ROCK W/CLAY BLUE GRAY MED.

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BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ____ Date 22 SEPT 81
Location DOWNSTREAM TOE Job No. ____
Drill Rig CE 4522 Inspector KEN LOYD Operator FRANK STEWART Surface El ____ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	CONTAINER	BLOWS	CLASSIFICATION AND REMARKS
24	22 SEPT			61.5	65.1	62.8	65.1	R-BARREL	CORE BOX	-	BASALT ROCK - LOST 1.3' W/CLAY BLUE MED.
25	22 SEPT			65.1	67.3	65.9	67.3	R-BARREL	CORE BOX	-	BASALT ROCK - LOST 0.8' W/CLAY BLUE MED.
26	23 SEPT		70.0	67.3	70.0	69.3	70.0	R-BARREL	CORE BOX	-	BASALT ROCK W/CLAY BLUE MED. - LOST 2.0'
27	24 SEPT	70.0		70.0	70.5	70.0	71.5	SPLITSPOON	JAR	10	MUD STONE, GRAY STIFF CLAY
				70.5	71.0					23	
				71.0	71.5					37	
28	24 SEPT			71.5	73.0	71.7	73.0	PITCHER TUBE	CARD BOARD	-	MUD STONE STIFF GRAVEL LOST 0.2'
29	24 SEPT			73.0	74.2	73.0	73.6	PITCHER TUBE	CARD BOARD	-	MUDSTONE GRAY STIFF CL, LOST 0.6'
30	24 Sept			74.2	76.2	74.6	76.2	PITCHER TUBE	CARD BOARD	-	MUDSTONE GRAY STIFF CL, LOST 0.9'

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Sheet 6 of 7 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ____ Date 22SEPT 81
Location DOWNSTREAM TOE Job No. ____
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ____ Boring No. SS-1 "E"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER	RECOVERY	BLOWS	CLASSIFICATION AND REMARKS
31	24SEPT			76.2	78.2	76.2	78.2	PITCHER TUBE	WAX TUBE	-	MUDROCK, GRAY STIFF CL
32	24SEPT			78.2	80.2	78.2	80.2	PITCHER TUBE	WAX TUBE		MUDROCK, GRAY STIFF CL
33	25SEPT			85.0	87.0	85.0	87.0	PITCHER TUBE	WAX TUBE		MUDROCK, GRAY STIFF CL
34	25SEPT			90.0	92.0	90.0	92.0	PITCHER TUBE	WAX TUBE		MUDROCK, GRAY STIFF CL
35	25SEPT			95.0	97.0	95.0	97.0	PITCHER TUBE	WAX TUBE		MUDROCK, GRAY STIFF CL
36	25SEPT			97.5	99.5	97.5	99.5	PITCHER TUBE	WAX TUBE		MUDROCK, GRAY STIFF CL ROCK BIT 6 3/4"

* 2" OD X 1 3/8" I.D. X 2 Ft LONG SPLITSPOON DRIVEN WITH 140-lb HAMMER W/30" DROP

** Hole CASED 4/4" I.D. PVC PIPE WITH CAP ON BOTTOM, PUSHED DOWN to 100', LOW ALK TYPE II CEMENT-WATER GROUT USED FROM 50' to 100' DEPTH, 1 PART CEMENT W/1 PART GEL PLUS WATER USED FROM 0' to 50' DEPTH, Hole CHECKED W/3 7/8" STEEL DUST TUBE DOWN TO 100'

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Sheet 7 of 7 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 29 SEPT 81
Location DOWN STREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. US-1 "F"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
—	29 SEPT	0.0		0.0	2.0			NONE			Rock Bit 8 3/4" to start Dennison Barrell GRAY SAND - COARSE
1	29 SEPT			2.0	4.0	NONE		6" DENNISON		*	No Sample, Gray Sand - Coarse
2	29 SEPT			4.0	6.0	NONE		6" DENNISON		*	No Sample, Gray Sand - Coarse
3	29 SEPT			6.0	8.0	6.8	8.0	6" DENNISON	Jar	6" Tube	Gray Sand - Coarse
4	29 SEPT		10.0	8.0	10.0	9.0	10.0	6" DENNISON	Jar		Gray Sand - Coarse, 6" Tube Sample Discarded, Sample Contaminated
5	29 SEPT	10.0	12.0	10.0	12.0	10.5	12.0	6" DENNISON	Jar		Gray Sand & 1/2" Agg., Tube Contaminated
6	29 SEPT	12.0		12.0	14.0	NONE		—			Rock Bit 8 3/4" - Unable to Sample Gray Rocks and Gravel
7	29 SEPT			14.0	16.0	NONE		—			Rock Bit 8 3/4" - Unable to Sample Gray Rocks and Gravel

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*Dennison Barrell will not Hold this Sand

Sheet 1 of 3 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 29 SEPT 81
Location DOWN STREAM TOE Job No. ______
Drill Rig CE 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. US-1 "F"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
			17.0								
8	29 SEPT	17.0		16.0	18.0	17.5	18.0	6" DENNISON	JAR		BLUE SANDY CLAY STARTED AT 17.0' MED
9	30 SEPT		19.0	18.0	20.0	NONE		ROCK BIT 8 3/4"			ROCK BIT 8 3/4" - BLUE SANDY CLAY WITH ROCKS MED.
		19.0									
10	1 OCT			20.0	22.0	21.6	22.0	6" DENNISON	JAR		BLUE SANDY CLAY MED.
11	1 OCT			25.0	27.0	NONE		6" DENNISON	—		BLUE SANDY CLAY - NO SAMPLE IN TUBE
12	1 OCT			30.0	32.4	30.1	32.4	6 1/4" BIT 5" CORE BARREL	5" TUBE		BLUE SANDY CLAY - CHANGED TYPES OF CORE BARREL - GOOD SAMPLE, MED.
13	1 OCT			35.0	37.4	35.8	37.4	5" X 6 1/4" CORE BARREL	5" TUBE		BLUE SANDY CLAY MED.
				35.0	STARTED REAMING WITH 6 3/4" ROCK BIT						
14	1 OCT		40.0	40.0	40.5	40.0	40.5	5" X 6 1/4" CORE BARREL			HARD BLUE CLAY WITH SMALL ROCKS
				40.5	48.0			6 3/4" ROCK BIT			REAM UNABLE TO SAMPLE
15	2 OCT			48.0	49.0	48.1	49.0	5" X 6 1/4" CORE BARREL	5" TUBE		BLUE CLAY WITH ROCKS, MED.

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Sheet 2 of 3 Sheets

BORING LOG
FIELD DATA

Project BLACK BUTTE DAM Site ______ Date 2OCT81
Location DOWNSTREAM TOE Job No. ______
Drill Rig CG 4522 Inspector OLEN LOYD Operator FRANK STEWART Surface El ______ Boring No. US-1 "F"

SAMPLE NUMBER	DATE TAKEN	STRATUM FROM	STRATUM TO	DRIVE FROM	DRIVE TO	SAMPLE FROM	SAMPLE TO	TYPE OF SAMPLER			CLASSIFICATION AND REMARKS
16	2OCT			51.0	53.4	51.1	52.4	5" x 6 1/4" CORE BARREL	5" TUBE		BLUE CLAY WITH ROCKS MED.
			70.0	51.0	70.0						REAM WITH 6 3/4" ROCK BIT THROUGH BLUE CLAY AND ROCKS - UNABLE TO SAMPLE
17	2OCT	70.0		70.0	72.4	70.0	72.4	5" x 6 1/4" CORE BARREL	5" TUBE		MUD ROCK (GRAY-BROWN CLAY) STIFF
18	2OCT			75.0	77.0	75.2	77.0	5" x 6 1/4" CORE BARREL	5" TUBE		MUD ROCK (GRAY-BROWN CLAY) STIFF
19	3OCT			80.0	82.4	80.0	81.1	5" x 6 1/4" CORE BARREL	JAR	5" TUBE	MUD ROCK (GRAY-BROWN CLAY) STIFF
20	3OCT			85.0	87.0	85.0	87.0	5" x 6 1/4" CORE BARREL	JAR	5" TUBE	MUD ROCK (GRAY-BROWN CLAY) STIFF
21	3OCT			90.0	92.4	90.0	92.4	5" x 6 1/4" CORE BARREL	JAR	5" TUBE	MUD ROCK (GRAY-BROWN CLAY) STIFF
22	3OCT			95.0	97.4	95.2	97.4	5" x 6 1/4" CORE BARREL	JAR	5" TUBE	MUD ROCK (GRAY-BROWN CLAY) STIFF
23	3OCT			97.4	99.7	97.5	99.7	5" x 6 1/4" CORE BARREL	JAR	5" TUBE	MUD ROCK (GRAY-BROWN CLAY) STIFF
					100.0						ROCK BIT WITH 6 3/4" TO 100'

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LOW ALK TYPE II

Sheet 3 of 3 Sheets

* HOLE CASED W/4" I.D. PVC PIPE WITH CAP ON BOTTOM, PUSHED TO 100'; CEMENT - WATER GROUT USED FROM 50' to 100' depth, 1 PART CEMENT W/1 PART GEL PLUS WATER USED FROM 0' to 50' Depth. Hole CHECKED W/5 7/8" STEEL INST. to 100'.

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Llopis, Jose L.
In situ seismic investigation of Black Butte Dam / by Jose L. Llopis and Ronald E. Wahl (Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. ; available from NTIS, 1982.
79 p. in various pagings : ill. ; 27 cm. -- (Miscellaneous paper ; GL-82-18)
Cover title.
"December 1982."
Final report.
"Prepared for U.S. Army Engineer District, Sacramento."

1. Black Butte Dam (Calif.) 2. Seismic waves. 3. Seismology. I. Wahl, Ronald. E. II. United States. Army. Corps of Engineers. Sacramento District. III. U.S. Army Engineer Waterways Experiment Station. Geotechnical

Llopis, Jose L.
In situ seismic investigation of Black Butte Dam : ... 1982.
(Card 2)

Laboratory. IV. Title V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; GL-82-18.
TA7.W34m no.GL-82-18

MEI

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